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Corporate Adaptation to the Impacts of Climate Change in the Logistics and Transportation Industry

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Foreword

Due to the emergence of shortages concerning natural resources and the globalization of production, sustainability has become vital in business decisions. Meanwhile, sustainability management has become an independent field of research in business science and in the decision processes of companies. The research and teaching of the Chair of Environmental Management and Accounting of the Technische Universität Dresden focus on the economic and environmental efficiency (e^3) in organizations. Strategies for practical use are developed based on scientific concepts. In recent years the importance of the natural environment in the economic sciences has been increasing continuously.

The research program of the Chair of Environmental Management and Accounting at the Technische Universität Dresden is reflected in the composition of the teachings. In this way the knowledge gained from the theoretical and practical research flows directly into each of the lectures. The current scientific series "Dresdner Beiträge zur Lehre der Betrieblichen Umweltökonomie" aims to support this integration process. Contents of the scientific series are predominantly theses selected from the Chair of Environmental Management and Accounting through which the reader may gain an insight into the key activities of the chair as well as a clear understanding of the work content.

The scientific series was composed by Dr. Susann Silbermann and the coordination of the present series was carried out by Dipl.-Kffr. Kristin Stechemesser.

The thesis aims at corporate adaptation to climate change impacts in the logistics and transportation industry, especially for the model region Dresden. The paper employs two analyses. The first part deals with a review of the current literature within the topic. 20 references are identified and analysed with a data extraction form. More general adaptation measures are identified in the current literature which can be implemented in the corporate strategy. Crucial effects on company's operation and its profit have flooding and sea level rise. In comparison adaptation measures, which are identified within five interviews of transportation providers in the model region Dresden, are of technological nature. The interviewed companies adapted significantly to weather extremes in the past. It is identified that heavy precipitation like rain and snow lead to crucial negative impacts to their operations which cause lost profit and customer dissatisfaction in long periods of time. On the other hand these weather conditions may have positive effects in short periods of time. Region-specific analyses in climate change impacts and the implementation of potential adaptation measures for logistics and transportation companies is still in a stage of infancy. Further research is needed on more region-specific analyses and on logistics companies in the model region Dresden as only five of them analysed in this thesis.

Edeltraud Günther

The scientific foundation of the work is based upon the results of the bachelor thesis by Josi Gwizdz which was written at the TU Dresden, Chair of Environmental Management and Accounting.
Professor/Lecturer: Prof. Dr. Edeltraud Günther / Supervisor: Dipl.-Kffr. Kristin Stechemesser. The author is solely responsible for the content of this scientific work.

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Abbreviations

Cf.	Compare
Comp.	Company
Ed.	Editor
e.g.	for example
et al.	and others
Hrsg.	Herausgeber
i.e.	in other words
IHK	Industrie- und Handelskammer
Jg.	Jahrgang
IPCC	Intergovernmental Panel on Climate Change
IT	Information technology
l.	line
o. S.	ohne Seitenangabe
p.	page
QDA	Qualitative Data Analysis
REGKLAM	Development and testing of an integrated regional climate adaptation program for the model region Dresden
S.	Seite
SLUB	Sächsische Landes- und Universitätsbibliothek
u. a.	unter anderem
USA	United States of America
Vol.	Volume

1 Introduction

„To date, there has been surprisingly little research conducted in the public domain on the impact of climate change on transportation systems"[1]. This gap has partially been closed by the REGKLAM project, which assess the effect of climate change on the local logistics and transportation industry of Dresden. Logistics is that part of the supply chain process that plans, implements, and controls the both, efficient as well as effective flow and storage of goods, services and related information from point of origin to point of consumption in order to meet customers' requirements[2]. Furthermore, transportation is a part of the logistics process and deals with the physical distribution of goods and services. It is in particular the service of carrying goods by road, air, water or rail.[3] Therefore, logistics and transportation processes are implemented in every single company and fulfill an important role for economy and society, which are depending highly on it. Additionally, these processes are exposed to daily weather conditions, which in comparison to the past have become more extreme due to climate change. "Climate change […] refers to any change in climate over time, whether due to natural variability or as a result of human activity. […] [It] is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods"[4]. These can cause interruptions to the logistics and transportation processes as well as to other company's operations. Extreme weather events are "[…] rare at a particular place and time of year [and] […] may vary from place to place […]"[5]. Hence, it is necessary to understand the potential impacts through it and how to adapt the service of logistics and transportation companies to the current and future impacts. "Adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"[6].

Due to the local appearance of weather conditions, it is recommendable to analyse climate change impacts and adaptation measures per region. Therefore, the REGKLAM-project, which aims at developing and implementing a regional climate change adaptation program for economy and community in the region Dresden,[7] has been set up. This thesis takes part in it to analyse the logistics and transportation industry. Thereby, it aims to answer the following research questions in general.

1. ***How does climate change affect the logistics and transportation industry?***
2. ***How do companies of the logistics and transportation industry adapt to climate change impacts?***
3. ***Are there any barriers for the implementation of specific adaptation measures?***

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1 Cf. TAYLOR, M. A. P.; PHILP, M. (2010), p. 4.
2 Cf. Council of Supply Chain Management Professionals (Ed.) (2012), o. S.
3 Cf. HESSE, M.; RODRIGUE, J.-P. (2004), p. 172.
4 Cf. IPCC (2007b), p. 6.
5 Cf. IPCC (2007a), p. 945.
6 Cf. IPCC (2007b), p. 6.
7 For more information please visit the website of REGKLAM (www.regklam.de).

4. ***What are open issues in this research field to ensure an effective protection against climate change?***

Specific research question for literature review and interview analysis are stated separately.

Answering these research questions is interesting from different perspectives. This thesis contains an in-depth analysis of climate change impacts on the global logistics and transportation industry. Secondly, from the results of the systematic literature review, research questions for analysing expert interviews of transportation providers in the model region Dresden are derived. To see how well logistics and transportation providers in the model region Dresden have adapted to climate change. Therefore only for Dresden relevant transportation modes are in scope in the literature review. Road transportation, rail transportation, water transportation and airports are in focus. The thesis only considers the impacts of climate change on the logistics and transportation branch. Impacts on climate change that are caused by the branch are not considered.

Figure 1 shows the outline of the thesis. To get an overview of the current literature dealing with this topic as well as already identified climate change impacts and adaptation measures, a literature review is covered in Chapter 2. Within the context of the thesis topic the step-by-step process of a literature review is shown. In Chapter 3, the approach of an interview analysis is described within the example of the model region Dresden. The next chapter, Chapter 4, assesses and discusses the results of the expert analysis and gives recommendations for the future. Finally, Chapter 5 summarizes.

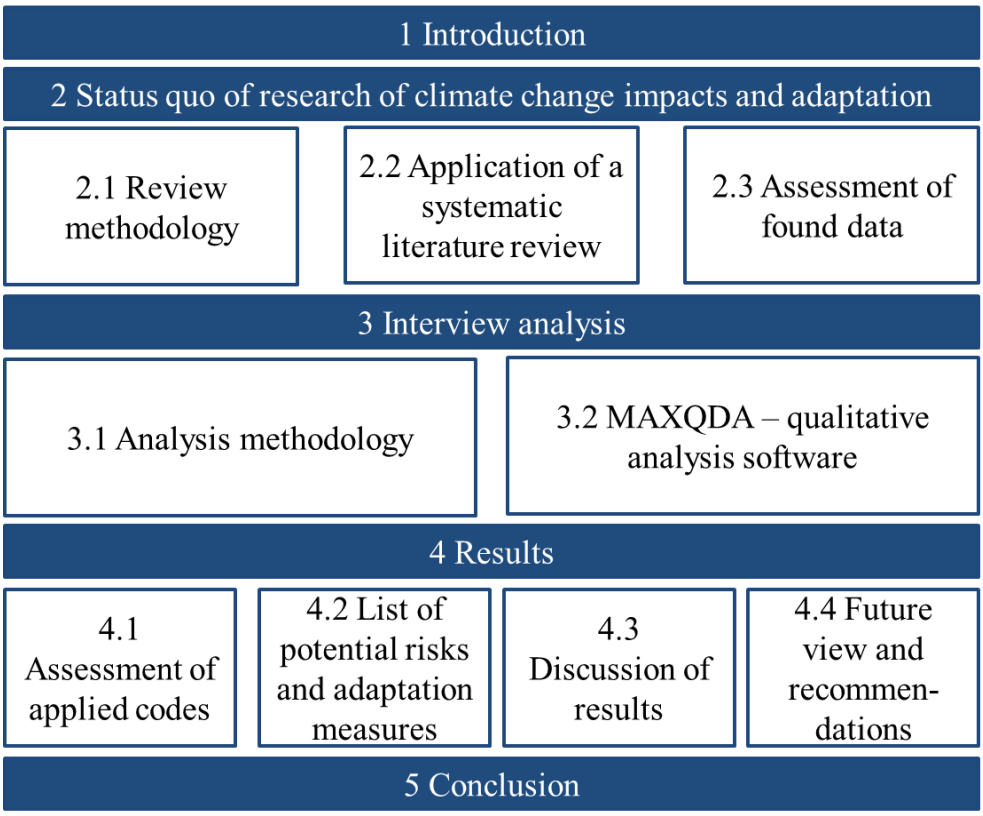

Figure 1: Outline of thesis
(Own illustration.)

2 Status quo of research of climate change impacts and adaptation

The following chapter gives an overview of the systematic literature review process that was carried out. In the beginning two review approaches are compared and the main steps of a literature review are identified. The second part of this chapter illustrates the application of the identified main steps on the research topic within the thesis.

2.1 Review methodology

To get an impression of the amount of current literature in a specific empirical topic and to handle a large body of writings, a systematic review is useful. LITTELL, J. H. et al. (2008) describe a systematic review as extensive and specific research, which includes research questions and uses a step-by-step process. As a result, the review becomes transparent and comprehensible for every reader. Furthermore, systematic reviews should minimise errors and bias, which can cause wrong interpretation of research results.[8]

The Conclusion of one's own research is based on works of researchers, scholars and practitioners. Therefore, a high-quality investigation gives the security of accurate review results.[9] Both processes are divided into several tasks. Table 1 compares these two methodological steps of a systematic literature review. To compare both approaches directly it is necessary to combine the five main steps of a systematic review.

Table 1: Comparison of systematic literature review approaches of LITTELL, J. H. et al. and FINK, A.

Steps	LITTELL, J. H. et al. (2008)	FINK, A. (2010)
1.	Topic formulation. Overall study design.	Select research questions.
2.	Sampling.	Select bibliographic or article databases, Web sites and other source. Choosing search terms.
3.	Data collection.	Applying practical screening criteria. Applying methodological screening criteria.
4.	Data analysis.	Doing the review. Synthesizing the results.
5.	Reporting.	

(Modeled after: LITTELL, J. H. et al. (2008), p. 21 and FINK, A (2010), p. 5.)

Both approaches are similar. For the following review the process of LITTELL, J. H. et al. (2008) is chosen, because its process is divided in more clearly defined sub-tasks.

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[8] Cf. LITTELL, J. H. et al. (2008), p. 1.
[9] Cf. FINK, A. (2010), p. 3.

2.2 Application of a systematic literature review

The main steps of the approaches of LITTELL, J. H. et al. (2008) and FINK, A. (2010) have several sub-tasks. To give an in-depth understanding of a systematic literature review the approach of LITTELL, J. H. et al. (2008) will be described in detail and applied to the research topic simultaneously.

First step: Topic formulation and overall study design

At the outset central questions such as research questions will guide the review. Therefore, they have to be identified and clarified. Furthermore, the purpose of the review, focus, scope and central assumptions need to be stated. Thus, an analysis framework is built.[10] In addition, the study design, which is the structure of the whole thesis, needs to be developed. It helps to answer the research questions and includes specific criteria, which are different from study to study like inclusion and exclusion criteria. These are e.g. publication year and language, year of study publication, duration of data collection or content of study.[11] Research questions and the study design are the basis for the whole empirical study.

In order to give an overview about the current literature and the state of research in general, the systematic literature review is an integrated part of the thesis. The thesis is focused on the impact of climate change on companies of the transportation sector. Furthermore, adaptation measures to protect the companies shall be identified. Therefore, the following research questions are ensued:

1. ***Which positive and negative effects of climate change on transportation providers do globally exist?***
2. ***How will transportation companies protect their business against extreme weather events and are there any barriers for measure implementation?***
3. ***What are open issues in this research field to ensure an effective protection against climate change?***

The scope of the thesis comprises simultaneously the exclusion criteria. Therefore, road transportation (bus, taxi, truck), rail transportation (tram, train, underground), water transportation (inland navigation, steam navigation, cruises) and for air transportation only the airport are in scope for the literature review. Furthermore, papers that deal with the impact of the transportation branch on climate change were excluded. Moreover, studies from all countries around the world are comprised to get an idea about how other nations deal with climate change impacts. Only studies written in English or German are considered. In general, there are no time limitations. Two exceptions were made for Google Scholar and the stock of the Sächsische Landes- und Universitätsbibliothek for time restriction. Only literature was searched for the time from 2007, when the Fourth Assessment Report of the IPCC[12] was published. An assumption is made that after the IPCC report of 2007 more companies have been aware of climate change impacts and thus, they have adapted to these impacts.

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[10] Cf. LITTELL et al. (2008), p. 31.
[11] Cf. FINK (2010), p. 59f.
[12] Intergovernmental Panel on Climate Change.

Second step: Sampling

In this stage a sampling plan, scoping review or systematic map is developed to get a rough overview where relevant studies are available. In this context the researcher should be aware of one problem. Only a subset of the relevant literature is available, because of difficulties in locating studies or studies are still in progress yet.[13] To obtain relevant studies different methods may help for instance bibliographic database, document harvesting, personal contacts or grey literature. Also appropriate search terms which are derived from research questions need to be defined and applied.[14] An important point in this step is the documentation of research with recordings of date, search term as well as used database in order to make it traceable.[15]

To find relevant studies coherent with impacts of climate change on transportation companies in the extensive bodies of scientific literature, central search terms, in particular transportation and logistics as well as climate change and global warming, are recognized. These main terms were combined with transportation related terms, and if is necessary, with truncation "*" extended. An example of combination of used search terms is shown in Table 2. A full list of all applied search terms and combinations is illustrated in Appendix A.

Table 2: Search terms for literature research

Climate	Action	Transportation
„climate change" „extreme weather" Klimawandel …	adapt* anpass*	transportation* logistic* Logistik* …

(Own illustration.)

The first selection process is based on searching in applicable databases. In this research the English electronic database system EBSCO Host, which includes the databases Academic Search Complete, Business Search Complete, EconLit and E-Journals, as well as Web of Science, Emerald Management and the German electronic database WISO Wirtschaftsdatenbank were used. Also, research was carried out in RSWB Plus, ICONDA ICBlibrary and Google Scholar. Some further studies were found through second selecting processes, i.e. document harvesting and manual search in professional journals from the stock of the Sächsische Landes- und Universitätsbibliothek Dresden.

In applying the search terms on databases some modifications were made. Because of the efficiency of search terms different amounts of search terms were applied. In all databases main search terms like "climate change" AND adapt* AND transport* or "global warming" AND adapt* AND logistic* were applied. Specifications like "inland navigation" or "supply chain" were merely applied in the main database. On the one hand to reduce the amount of redundant hits and on the other hand every database has a different focus. For instance Google Scholar yields 19.200 hits for the search term combination "transport* AND adapt* AND "climate

[13] Cf. LITTELL, J. H. et al. (2008), p. 53.
[14] Cf. LITTELL, J. H. et al. (2008), p. 56.
[15] Cf. FINK, A. (2010), p. 43f.

change"". Therefore the research was modified by entry settings in every single database. Furthermore, words like mitigation and production were excluded and subject areas were only Business, Administration, Finance and Economics. The end-result for screening was 444 hits but relevant literature was merely two results. After the database evaluation and screening process, reference lists of found sources were manually screened for further literature. Four sources were detected by document harvesting and found via Google Scholar subsequently. Thereby these papers are counted as results of Google Scholar. Recordings of research results in databases are included in Appendix B. Duplicates of literature were also documented. Figure 2 gives an overview about the research results.

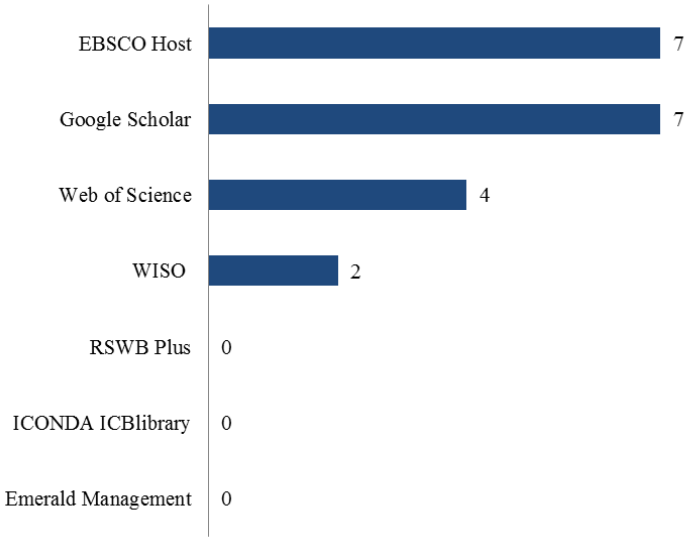

Figure 2: Research results database
(Own illustration.)

Third step: Data collection

The next phase is important to bring information from all identified studies into a comparable form. Therefore a data extraction form is needed. The form is divided in several sections (e.g. initial screening, eligibility decisions, data extraction and study level). Inclusion criteria which were identified earlier were also part of this form.[16]

In order to answer the research questions, specific codes were developed. 20 recognised studies were analysed with the same form in the same way. Table 3 shows the structure of the data extraction form. All forms of analysed studies are part of Appendix C.

The first part of the data extraction form asks for general information. Number one to four summarize title of the article, the author's name, year of publication and country of origin. Thus every form is easily identified from all 20 sources. Additionally, number five to seven mention some quality criteria such as the publication type (book, journal, report, grey literature or working paper) as well as the ISI-impact factor, which is defined in the assessment.

[16] Cf. FINK, A. (2010), p. 99f.

Furthermore, number eight and nine show the way of finding every single study, i. g. databases and search terms.

The second part, number ten to thirteen, deals with information about the specific study. Paper type can be empirical, theoretical or practical. It has happened that the author has not mentioned the paper type. In this case it is derived from the paper method. Empirical work refers to a systematic and standardised process to enhance knowledge about a research object or question. Theoretical work describes only a theory and it does not refer to any practical measures. Practical work neither answers research questions nor does it describe a theory. In case of an empirical background the method such as case studies, content analysis or scenario analysis is mentioned. Furthermore, the criterion geographical region is divided into local and global. If the paper focuses on the area of one city then "Local" is entered, but if it is focused on a whole country or more then "Global" is entered.

Table 3: Data extraction form

1. Title	15. Weather condition	Short run
2. Author		Long run
3. Publication year	16. Risks	Literature review
4. Country of origin		Survey, interviews, etc.
5. Publication type	17. Opportunities	Literature review
6. Source		Survey, interviews, etc.
7. ISI-impact factor	18. Adaptation measures	Literature review
8. Database		Survey, interviews, etc.
9. Search terms	19. Adaptation strategy	Literature review
10. Paper type		Survey, interviews, etc.
11. Paper method	20. Barriers of implementation	
12. Geographical region	21. Open research issues	
13. Research period	22. Remarks	
14. Transportation mode		

(Own illustration.)

The last part, number fourteen to twenty-one, deals with the research questions within this paper. To show the impact of weather conditions on a specific transportation mode, road, rail, water transportation and airports may be chosen. The category "Weather condition" includes sub-categories such as heat waves, cold waves, storm and storm surges, heavy rain, flooding, snow and sea level rise and are counted they are mentioned in the study. Furthermore, risks, opportunities, adaptation measures or strategies should be identified. All four criteria are divided in literature review and survey, interviews, etc., to see if data is new or has already been evaluated. Additionally, results of categories for risks and opportunities were assessed, if they are financial, competitive, physical or regulatory. To see the distinction all sub-criteria state-

ments were colored. Financial is red, competitive is blue, physical is black and regulatory is green. Adaptation measures were classified in five colored sub-categories: technological (black), ecological (green), economic (blue), social (red) and political (brown). All sub-criteria are defined in Chapter 3. Thus, these sub-categories help to make later assessments of identified data more comprehensible. The last three criteria were not divided by sub-criteria, since no big differences between the statements are identified.

Fourth and fifth step: Data analysis and Reporting

According to LITTELL, J. H. et al. (2008), several methods like effect size, standardized mean difference, odds ratio or risk ratio can be applied on collected information. There are different methods to analyse the found data and to answer the research questions.[17] To make the results of data analysis more logical, tables and graphs can be created in the last step. Afterwards a discussion is drawn and implications for policy, practice and further research is given.[18]

With the data extraction form a lot of data was identified. The assessment of these data is given in order to the data extraction form to make it comprehensible to the reader.

Definition of sub-categories

As stated previously in the data extraction form, risks, opportunities and adaptation measures are divided in sub-categories to assign identified aspects. Risks and opportunities are divided in physical, competitive, financial and regulatory. In the end, every weather impact leads to increasing or decreasing costs and therefore to effects on the financial sub-category. To compare all risks and opportunities, it is necessary to differentiate all mentions. Other sub-categories are given for adaptation measures, such are technological, economic, ecological, social and political. The detailed definitions of all sub-categories are given below:

Physical: Mentions are assigned to this category when they include information about impacts on technical aspects or infrastructure of transportation providers, like rail buckling[19], affecting of drainage systems[20] as well as fewer winter problems through milder winter.[21]

Competitive: Impacts of this category affect the competiveness of the logistics and transportation industry. Mentions, which include lost trips, longer travel time and delays[22] and are therefore not attractive to costumers, are included.

Financial: Mentions are counted to this category, only if they include information about costs or aspects, which lead to cost increases or decreases. For example, weather impacts lead to economic costs through lost work-days, lost sales or lost production because of unavailable material.[23]

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17 Cf. MAYRING, P. (2010), p. 63ff.
18 Cf. LITTELL, J. H. et al. (2008), p. 139.
19 Cf. LINDGREN, J. et al. (2009), p. 169.
20 Cf. REGMI, M. B. et al. (2011), p. 26.
21 Cf. LINDGREN, J. et al (2009), p. 172.
22 Cf. SUAREZ, P. et al. (2005), p. 231ff.
23 Cf. SUAREZ, P. et al. (2005), p. 234.

Regulatory: Implications of this category on a company are due to political guidelines within climate change. In a negative way, companies are restricted in their operations due to these guidelines. In a positive way, companies can plan their operations efficiently because every company has to meet these guidelines.

Technological: Adaptation measures of this category deal with improvements of technological aspects like buses, trains or drainage systems against flooding.

Economic: Adaptation measures of this category lead to higher profit or strengthen the competitiveness of a company or the whole branch.

Ecological: Adaptation measures of this category do not influence the environment and are especially economically friendly.

Social: This category focuses on adaptation measures coherent with other stakeholders like other members of the industry, employees or customers.

Political: Adaptation measures of this category are implemented through political guidelines.

2.3 Assessment of found data

In the following chapter nearly every single category of the data extraction form is assessed. An overview of the frequency of the identified aspects is given as well as an interpretation of the found data. References from the categories “Publication year” to “Weather condition” are evident in Appendix C and are not mentioned in the assessment.

Publication year

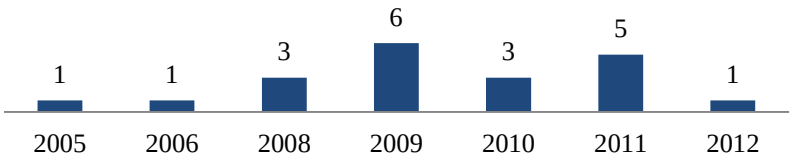

Figure 3: Number of references per year
(Own illustration.)

As shown in Figure 3, more than half of the analysed studies were published in 2009 or 2011. Before 2009 studies about climate change impacts on the transportation industry are rare. In 2010 three studies are published which might be the result of the hype in 2009. Publications in 2009 might have resulted of the IPCC Report of 2007. Conceivably, this report raised the awareness of companies to climate change impacts. Also it shows the need for further research in this field. In 2011 publications in this research field raised again, which shows that the topic is still in the focus of companies as well as in scientific research.

Country of origin

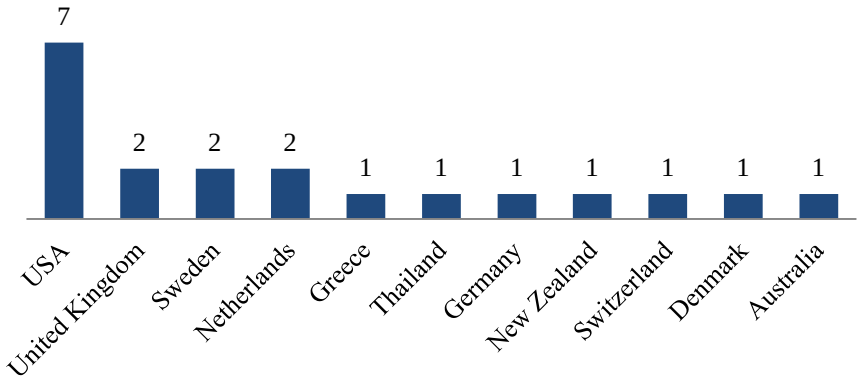

Figure 4: Number of references sorted by country of origin
(Own illustration.)

To classify the geographical origin of the paper, the origin of the first author is used. As shown in Figure 4, countries all around the world focus on this topic. The majority of references originate from the United States of America. This can be explain with the large amount of extreme weather events in past years[24] and the awareness of climate change impacts is higher than in other countries. Only economically interacting countries deal with the issue of climate change. On the one hand other countries like African or South American countries do not have the monetary support to carry out publications on this topic. On the other hand they might not have these extreme weather events which might be affect their supply chains.

Publication and paper type

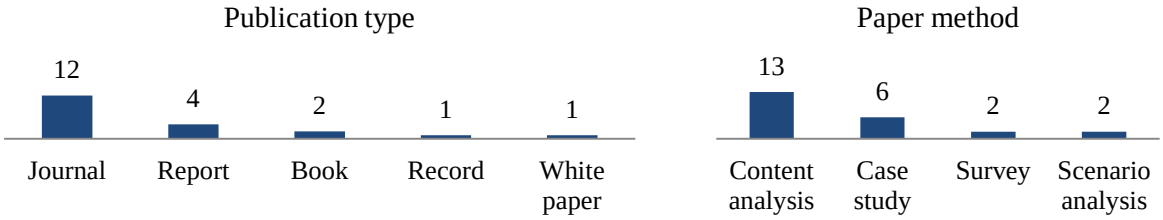

Figure 5: Comparison of references sorted by publication and paper type
(Own illustration.)

All studies are empirical, because they include a standardised process and at least one research question, which are criteria for empirical methodology[25]. The most references of this topic are published in journals because articles in journals do not have the range of a book or a report. As shown in Figure 5, research on climate change impacts on transportation and their adaptation to it is relatively young. Therefore scientists publish their gained research results step-by-step, before they publish a whole book about the issue.

[24] Cf. GALLAGHER, T. L. (2009), p. 9.
[25] Cf. BÜLOW-SCHRAMM, M. et al. (2009), p. 2.

The most common research methodology is the content analysis, which is also shown in Figure 5. Furthermore, six case studies are used as the methodology. Sometimes a content analysis and another methodology are combined in a paper to show the current status of the issue followed by the specific research. The latest research is from EISENACK, K. et al. (2012).

63 studies are identified in the content analysis, but not all studies deal with impacts and adaptation measures on the logistics and transportation industry. This shows that the topic should be addressed more with the methodology of case studies and surveys to identify the impacts on companies through climate change.

ISI-impact factor of journals

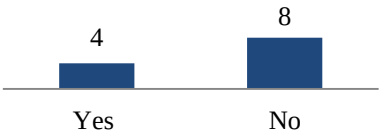

Figure 6: Number of journals with an ISI-impact factor
(Own illustration.)

ISI-impact factor of journals is used to evaluate institutions, scientific research, entire journals, and individual articles. The performance of a journal is the balancing of publication and citation counts. Therefore the impact-factor is also used as a quality criterion, but it is not a guarantee for high quality studies.[26]

As shown in Figure 6, four journals have impact-factors. The highest factor of 3.106 has got the journal "Climatic Change" with the study from KIRSHEN, P. et al. (2008). Other studies with an impact factor are written by PROWSE, T. D. et al. (2009) (1.705), ARNBJERG-NIELSEN, K.; FLEISCHER, H. S. (2009) (1.056) and HAWKES, P. et al. (2010) (0.162). The half of the journals within the identified references, which are published in journals, have an impact-factor. This means, that the issue of climate change impacts is sometimes represented in some higher ranked journals, but there is still a gap for further research.

Geographical region of research

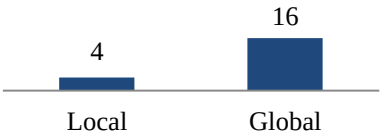

Figure 7: Number of references sorted by geographical region of research
(Own illustration.)

In the assessment within these papers "Local" is defined as a city, town or a small region. Compared to this, "Global" is defined as a whole country or many countries. At the present state and as shown in Figure 7, more studies are focused on a global scale. Merely four stud-

[26] Cf. GARFIELD, E. (2002), p. 363ff.

ies consider climate change impacts on a local scale. SUAREZ, P. et al. (2005) and KIRSHEN, P. et al. (2009) show climate change impacts on Boston's underground. ARKELL, B. P.; DARCH, G. J. C. (2006) carried out the impacts and adaptation measures and strategy for the London underground, as well as WALKER, L. et al. (2011) for the Portland transportation surface. All of these studies identify impacts but merely two of them give some adaptation measures or strategies. Furthermore, more than three quarter of all references within these papers have a global scope. Hence, described risks and adaptations are general. But precipitation and temperature patterns which cause risks, should be identified locally and therefore have local adaptation implementations.[27]

Research period

Within the 20 references six[28] mention the research period. Especially references which contain a case study or a survey mention it. This results of the importance of time scale when a study is done. Time ranges of content analyses can be identified through the publication dates of the considered references. Thus, only EISENACK, K. et al. (2012) state the time range of the analysed papers within the content analysis.

Transportation mode

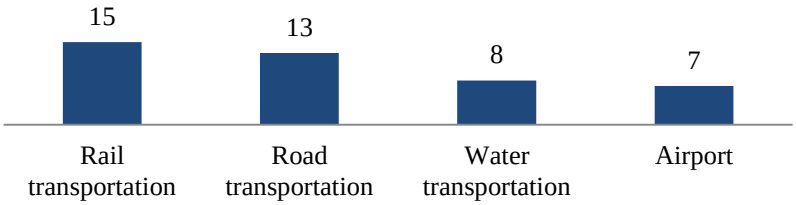

Figure 8: Number of identified transportation modes in references
(Own illustration.)

All references deal with one or more transportation modes. Figure 8 gives an overview about the amount of identified transportation modes within all papers. Rail transportation with 15 mentions and road transportation with 13 mentions are the most examined transportation modes. This can be explained by the fact that rail and road transportation are available in every region of the world. Furthermore, rail transportation contains trains and underground and road transport contains bus, taxi and trucks which are used frequently. Additionally, the papers are focused hardly on inland navigation as well on airport management. Global shipping and air transportation are not included. Only few regions have rivers or sea access and thus are vulnerable to climate change impacts. Climate change impacts on airports are very specific issues and therefore, the research on it does not have the same size as rail transportation.

[27] Cf. KRISHEN, P. et al. (2008), p. 461.
[28] Cf. JONKEREN, O. (2009), p. 22; ARKELL, B. P.; DARCH, G. J. C. (2006), p. 234; WALKER, L. et al. (2011), p. 6; REGMI, M. B.; HANAOKA, S. (2011), p. 30; EISENACK, K. et al. (2012), p. 2; GARDINER, L. et al. (2008), p. 18.

Weather condition

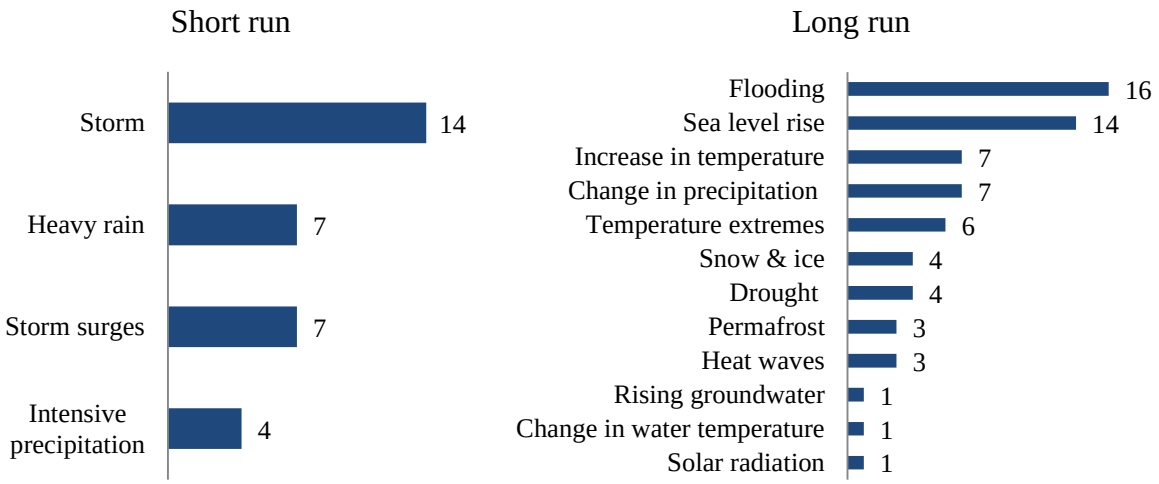

Figure 9: Number of mentioned short- and long run weather conditions (Own illustration.)

Companies of the logistics and transportation industry are exposed to weather changes every day. Therefore, weather conditions have a high impact on this branch. It is necessary to identify the most influential weather condition to derive potential adaptation measures and strategies.

The assessment of weather conditions is divided in categories “Short run” and “Long run”. Short run weather events are precipitation and storms which are extreme on one day. Long run weather conditions persist for a longer period. Both cases cause high impact on the logistics and transportation industry. Figure 9 is divided in these weather conditions categories. In the short run category storm events are mentioned more often than any other weather condition in the identified papers (14 mentions). Heavy rain (7 mentions) and storm surges (7 mentions) are equal. Compared to long run weather conditions, short run weather conditions take a small part in consideration within the papers. It is obvious in Figure 9, that long run weather conditions are more often identified than short run. The transportation branch is most vulnerable to flooding (16 mentions) and sea level rise (14 mentions). Sea level rise is not an impact in all regions because of their geographical position. Increases in temperatures (7 mentions) as well as change in precipitations (7 mentions) and temperature extremes (6 mentions) are general weather conditions and cause risks over a longer time range. Some weather conditions, e.g. rising temperatures, also lead to opportunities, e.g. safer trips, for logistics and transportation companies. [29] Therefore extreme weather events can show positive and negative impacts.

[29] Cf. KOETSE, M. J.; RIETVELD, P. (2009), p. 214.

Risks through weather extremes

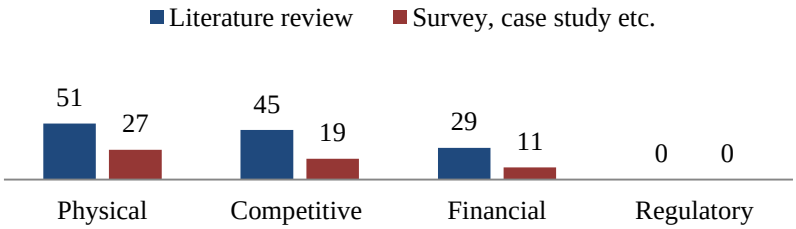

Figure 10: Number of mentioned risk mentions sorted by risk type (Own illustration.)

The logistics and transportation industry is vulnerable to weather extremes, because the services of these companies are highly exposed to weather patterns. In the 20 references many risks are identified and assigned to four categories. These are shown in Figure 10.

In literature reviews, most risks are physical, which are mentioned 51 times. This can be explained that impacts to company's assets are perceived directly. Physical risks have a direct impact on transportation technologies and infrastructure. Risks through flooding are mentioned nine times. This includes effects on drainage-systems, culverts, landslides and destroying bridges.[30] Furthermore, extreme heat leads to pavement damages[31], rail buckling[32] and breaking down of computer facilities[33]. Additionally, extreme winds cause overhead cables to break[34] and therefore disrupt rail operations.

Competitive risks are mentioned 45 times, since analysts of the current state derive competitive risks to the company from the physical risks. Therefore the amount of both categories is nearly similar. Weather extremes are highly risky in the competitive way. Most identified competitive risks are delays[35] (10 mentions) which affects all transportation modes. Furthermore, through higher temperatures the water levels of rivers decrease and therefore, the load capacities of ships have to be reduced[36] (3 mentions). This is a risk for inland navigation, because more trips are needed for the same amount which causes higher costs.[37] Disruptions (5 mentions) in traffic[38] and supply chains[39], closure of roads, rails and airports[40] and the damage

30 Cf. ARKELL, B. P.; DARCH, G. J. C. (2006), p. 233; HAWKES, P. et al. (2010), p. 61; GALLAGHER, T. L. (2009), p. 18; PAPPIS, C. P. (2011), p. 112; STEWART, B. et al. (2011), p. 41; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 89; TAYLOR; M. A. P.; PHILP; M. (2010), p. 69.

31 Cf. REGMI, M. B.; HANAOKA, S. (2011), p. 26; GALLAGHER, T. L. (2009), p. 19; PAPPIS, C. P. (2011), p. 112; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 84; TAYLOR; M. A. P.; PHILP; M. (2010), p. 69.

32 Cf. LINDGREN; J. et al. (2009), p. 169, REGMI, M. B.; HANAOKA, S. (2011), p. 26; LOVE, G. et al. (2010), p. 135; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 88; TAYLOR; M. A. P.; PHILP; M. (2010), p. 69.

33 Cf. STEWART, B. et al. (2011), p. 41.

34 Cf. GALLAGHER, T. L. (2009), p. 20; PAPPIS, C. P. (2011), p. 112.

35 Cf. SUAREZ, P. (2005), p. 231; GALLAGHER, T. L. (2009), p. 21; EISENACK, K. et al. (2012), p. 452; LOVE, G. et al. (2010), p. 135; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 92; KOETSE, M. J.; RIETVELD, P. (2009), p. 206, 209, 212, 214; TAYLOR; M. A. P.; PHILP; M. (2010), p. 71.

36 Cf. JONKEREN, O. (2009), p. 13; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 86; HAWKES, P. et al. (2010), p. 59.

37 Cf. JONKEREN, O. (2009), p. 13.

38 Cf. REGMI, M. B.; HANAOKA, S. (2011), p. 25.

39 Cf. LOVE, G. et al. (2010), p. 135.

of facilities[41] which cause lost trips (3 mentions)[42] and lead therefore to customer and contractor dissatisfaction[43]. This in turn leads to high costs for the logistics and transportation industry.

All previously mentioned risks lead to high costs for the logistics and transportation industry as well as for their customers. Identified financial risks are mentioned 29 times. These are divided in operation costs (10 mentions)[44] e.g. delays and investments in new resistant facilities, maintenance and repair costs (8 mentions)[45] e.g. damage to infrastructure, economic costs (6 mentions)[46]. Furthermore, disruptions lead to lost production and higher energy consumption (4 mentions)[47] e.g. rising in air-conditioning as well as fuel usage[48]. Moreover, TAYLOR; M. A. P.; PHILP; M. (2010) state due to increasing of understanding of climate change impacts, insurers may be reduce their event coverage for climate change impacts.[49] Therefore, companies have to cover damages on facilities by their own.

In surveys, case studies, etc. physical risks (27 mentions) are mentioned more often than competitive risks (19 mentions) and financial risks (11 mentions). In the case of surveys, the same risks are identified as in the literature review. Therefore, a rough overview of main risks of all three categories is given. Main physical risks are flooding which lead to drainage problems[50] (5 mentions) and infrastructure damage[51] (4 mentions). Extreme heat leads to intensive cooling (2 mentions)[52] especially in the underground. Competitive risks are increases in delays (4 mentions)[53] and customer dissatisfaction (2 mentions)[54]. Financial risks are repair costs (5 mentions)[55] and operational costs (2 mentions)[56].

Regulatory risks within the sub-categories "Literature review" and "Survey, case study etc." due to political guidelines are not identified.

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40 Cf. REGMI, M. B.; HANAOKA, S. (2011), p. 26; LOVE, G. et al. (2010), p. 135; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 86, 92.

41 Cf. PAPPIS, C. P. (2011), p. 94; KOETSE, M. J.; RIETVELD, P. (2009), p. 209.

42 Cf. KOETSE, M. J.; RIETVELD, P. (2009), p. 115; SUAREZ, P. (2005), p. 231, 234.

43 Cf. STEWART, B. et al. (2011), p. 41.

44 Cf. REGMI, M. B.; HANAOKA, S. (2011), p. 26; GALLAGHER, T. L. (2009), p. 16; PAPPIS, C. P. (2011), p. 112; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 86, 89; KOETSE, M. J.; RIETVELD, P. (2009), p. 112, 117, 209, 211; TAYLOR; M. A. P.; PHILP; M. (2010), p. 70.

45 Cf. REGMI, M. B.; HANAOKA, S. (2011), p. 25f., 28; GALLAGHER, T. L. (2009), p. 22; PAPPIS, C. P. (2011), p. 111; KOETSE, M. J.; RIETVELD, P. (2009), p. 209; TRANSPORATION RESEARCH BOARD (Ed.)(2008), p. 86; TAYLOR; M. A. P.; PHILP; M. (2010), p. 69.

46 Cf. PROWSE, T. D. (2009), p. 279; SUAREZ, P. (2005), p. 234; GALLAGHER, T. L. (2009), p. 21; JONKEREN, O. (2009), p. 12; STEWART, B. et al. (2011), p. 41.

47 Cf. GALLAGHER, T. L. (2009), p. 21; PAPPIS, C. P. (2011), p. 113; STEWART, B. et al. (2011), p. 41; KOETSE, M. J.; RIETVELD, P. (2009), p. 211.

48 Cf. TAYLOR; M. A. P.; PHILP; M. (2010), p. 71.

49 Cf. TAYLOR; M. A. P.; PHILP; M. (2010), p. 71.

50 Cf. GARDINER, L. et al. (2008), p. 75; ARKELL, B. P.; DARCH, G. J. C. (2006), p. 234; LINDGREN; J. et al. (2009), p. 171, 172; KRISHEN, P. et al. (2008), p. 462.

51 Cf. WALKER, L. et al. (2011), p. 6; GARDINER, L. et al. (2008), p. 75; ARKELL, B. P.; DARCH, G. J. C. (2006), p. 234; LINDGREN; J. et al. (2009), p. 171.

52 Cf. ARKELL, B. P.; DARCH, G. J. C. (2006), p. 235; LINDGREN; J. et al. (2009), p. 172.

53 Cf. ARNBJERG-NIELSEN, K.; FLEISCHER, H. S. (2009), p. 277; ARKELL, B. P.; DARCH, G. J. C. (2006), p. 235; WALKER, L. et al. (2011), p. 5; GARDINER, L. et al. (2008), p. 88.

54 Cf. JONKEREN, O. (2009), p. 129; ARKELL, B. P.; DARCH, G. J. C. (2006), p. 233.

55 Cf. GARDINER, L. et al. (2008), p. 77; ARKELL, B. P.; DARCH, G. J. C. (2006), p. 235; ARNBJERG-NIELSEN, K.; FLEISCHER, H. S. (2009), p. 276; KRISHEN, P. et al. (2008), p. 461.

56 Cf. ARNBJERG-NIELSEN, K.; FLEISCHER, H. S. (2009), p. 276; JONKEREN, O. (2009), p. 117.

To sum up, weather conditions like flooding, storm and heat have the most vulnerable impacts to logistics and transportation companies. These impacts lead to high costs in every operation, adaptation as well as in economic costs.

Opportunities through weather conditions

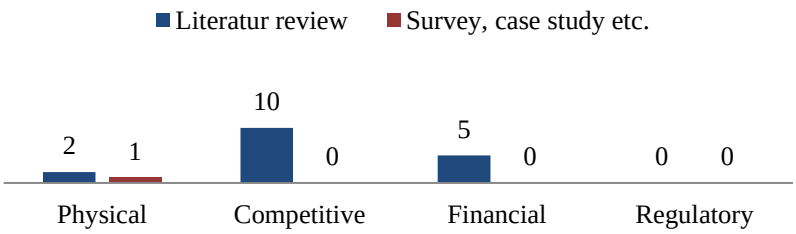

Figure 11: Number of identified opportunity mentions sorted by opportunity type (Own illustration.)

Opportunities through extreme weather conditions are merely identified in literature reviews (18 mentions) which are shown in Figure 11. Most opportunities are competitive (10 mentions). This is the reflection of risks through weather conditions. Every company recognised positive and negative effects in the buying behaviour of their customers. HAWKES, P. et al. (2010) and JONKEREN, O. (2009) show, that especially inland navigation is influenced positively by climate change. Firstly, inland navigation is a low-emission alternative to road and rail freight.[57] Secondly, inland navigation is not as vulnerable to extreme weather conditions as road and rail transportation. Therefore, a shift from rail and road transport to inland navigation could develop.[58] SCHWARTZ, H. G. Jr. (2011), PROWSE, T. D. et al. (2009) and GALLAGHER, T. H. (2010) identified another benefit for inland navigation through warmer winters. These lead to a longer operation period because of increasing ice free rivers.[59] Furthermore, higher temperature is a benefit to rail infrastructure[60], transportation safety[61] and therefore leads to fewer delays. These positive impacts lead to saving maintenance cost[62] and lower costs in snow and ice control[63] as well as reductions in fuel costs[64]. Only one positive impact is identified in a survey. LINDGREN, J. et al. (2009) identified that milder winters may lead to fewer problems with train engines, track switches and train set doors.[65] Furthermore regulatory opportunities are not identified.

All in all, only a moderate rise in temperature leads to a few benefits in the transportation branch. Inland navigation providers have the most positive impact through a longer operation season. Rail and road transportation can provide safer trips. All transportation providers will save some costs through this weather impact.

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57 Cf. JONKEREN, O. (2009), p. 42.
58 Cf. HAWKES, P. et al. (2010), p. 62.
59 Cf. SCHWARTZ, H. G. Jr. (2011), p. 2; GALLAGHER, T. L. (2009), p. 21; PROWSE, T. D. (2009), p. 277.
60 Cf. LINDGREN, J. et al. (2009), p. 168.
61 Cf. KOETSE, M. J.; RIETVELD, P. (2009), p. 214.
62 Cf. GALLAGHER, T. L. (2009), p. 16.
63 Cf. LOVE, G. et al. (2010), p.135.
64 Cf. KOETSE, M. J.; RIETVELD, P. (2009), p. 211.
65 Cf. LINDGREN, J. et al. (2009), p. 172.

Adaptation measures

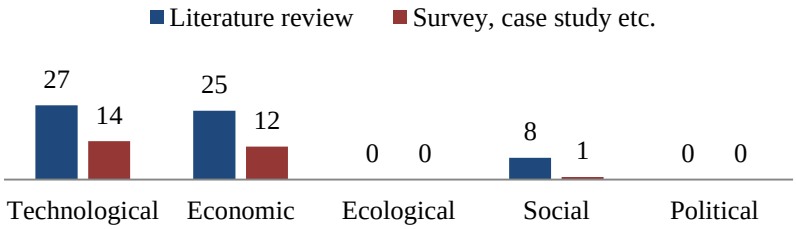

Figure 12: Number of identified adaptation measures mentions sorted by measure type (Own illustration.)

All found adaptation measures were assigned to sub-categories, which were previously defined. In Figure 12 an overview of the division is given. Economic and technological adaptation measures have nearly the same amount of mentions in the references for the category "Literature review" compared to the category "Survey, case study etc.". Most risks are in these both categories. Companies adapt their operations first, because these have critical impacts on their profit. More adaptations measures are identified in literature reviews, because more references used this methodology. Only main measures are stated, further adaptations are considered in Appendix C.

Technological adaptation measures include the lengthening of runways (3 mentions)[66], because of high temperature effects, to stable airports operations. Furthermore, the implementation of dikes (8 mentions)[67] protects airports as well as road and rail infrastructure against flooding and sea level rise. Additionally, adaptation measures are also the use of special material (5 mentions)[68], extension of drainage systems[69] and air conditioned vehicles[70]. In surveys, 14 adaptation measures of technological nature are identified. Adaptation to climate change impacts is relatively new for companies of the logistics and transportation industry and therefore, the companies adapt mainly necessary aspects. Technological measures in the survey include improvements of drainage systems (3 mentions)[71], cooling of vehicles (2 mentions)[72] and optimization of trains, which should operate in both directions[73].

Economical adaptation measures are actions, which a company undertakes in its administrative operations. 25 mentioned measures are identified in literature reviews. These comprise mapping of alternative routes (4 mentions)[74] in case of affected routes, monitoring of impacts

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66 Cf. PAPPIS, C. P. (2011), p. 112; LOVE, G. et al. (2010), p. 8; STEWART, B. et al. (2011), p. 40.

67 Cf. KRISHEN, P. et al. (2008), p. 462; REGMI, M. B.; HANAOKA, S. (2011), p. 28; EISENACK, K. et al. (2012), p. 458; LOVE, G. et al. (2010), p. 141; SCHWARTZ, H. G. Jr. (2011), p. 8; STEWART, B. et al. (2011), p. 41; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 92.

68 Cf. STEWART, B. et al. (2011), p. 40; GALLAGHER, T. L. (2009), p. 24; EISENACK, K. et al. (2012), p. 459; SCHWARTZ, H. G. Jr. (2011), p. 8; TAYLOR; M. A. P.; PHILP; M. (2010), p. 69.

69 Cf. REGMI, M. B.; HANAOKA, S. (2011), p. 28.

70 Cf. EISENACK, K. et al. (2012), p. 459.

71 Cf. ARNBJERG-NIELSEN, K.; FLEISCHER, H. S. (2009), p. 280; LINDGREN, J. et al. (2009), p. 173; ARKELL, B. P.; DARCH, G. J. C. (2006), p. 234.

72 Cf. LINDGREN, J. et al. (2009), p. 172; ARKELL, B. P.; DARCH, G. J. C. (2006), p. 236.

73 Cf. WALKER, L. et al. (2011), p. 10.

74 Cf. GALLAGHER, T. L. (2009), p. 24; EISENACK, K. et al. (2012), p. 458; SCHWARTZ, H. G. Jr. (2011), p. 8; TAYLOR; M. A. P.; PHILP; M. (2010), p. 71.

for solution shortcomings (3 mentions)[75], identifying of critical areas (6 mentions)[76] and integration of impacts in risks management[77] as well as involvement of investments (2 mentions)[78] e.g. for technological adaptations. In surveys within the literature analysis, 12 measures are identified. Economical adaptation measures are very wide-ranging. These include enhancing of train frequency[79] as well as life-cycle costs of facilities[80] and strategic warning and information systems (2 mentions)[81].

Moreover, social adaptation measures deal with employees, customers and contractors. In literature reviews, training of employees (2 mentions)[82], sharing of best practise (2 mentions)[83] and formation of collaborations (4 mentions)[84] are measures of the category "Social". Only ARKELL B. P.; DARCH, G. J. C. (2006) point out one social adaptation measure in surveys: Companies should better inform their customers in case of extreme weather impacts.[85] Therefore, customer satisfaction will not decrease, which is a crucial impact through climate change. Neither adaptation measures which are especially environmentally friendly nor measures through political guidelines are identified in literature reviews and surveys. If crucial operations are stable, companies might focus on ecological adaptations.

All in all, a lot of adaptation measures are given in the current literature and focus on different aspects in a company. Furthermore, adaptation measures in this branch are valid for nearly every transportation mode.

Adaptation strategy

Specific strategies are not given in the identified papers. Merely recommendations are given which are coherent with uncovered issues. Therefore, in this category only actions which should be integrated in the strategic alignment of a company to cope with climate change impacts on operations are included. In the category "Literature review", LINDGREN, J. et al. (2009) point out that a scenario analysis and a workshop of assessing identified risk and adaptation measures should be integrated in the strategy of a company. Furthermore, it should be analysed if synergies between company goals consist.[86] Additionally, STEWART, B. et al. (2011) recommend an integration of collaboration between branch members and stakeholders into strategic alignment.[87] Moreover, climate change risks should be integrated in planning systems[88] as well as emergency evacuation plans[89].

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75 Cf. SCHWARTZ, H. G. Jr. (2011), p. 6; HAWKES, P. et al. (2010), p. 61; TAYLOR; M. A. P.; PHILP; M. (2010), p. 74.
76 Cf. GALLAGHER, T. L. (2009), p. 24; EISENACK, K. et al. (2012), p. 458; SCHWARTZ, H. G. Jr. (2011), p. 8; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 171; TAYLOR; M. A. P.; PHILP; M. (2010), p. 69.
77 Cf. REGMI, M. B.; HANAOKA, S. (2011), p. 27.
78 Cf. LOVE, G. et al. (2010), p. 137; EISENACK, K. et al. (2012), p. 460.
79 Cf. ARKELL, B. P.; DARCH, G. J. C. (2006), p. 235.
80 Cf. REGMI, M. B.; HANAOKA, S. (2011), p. 34.
81 Cf. LINDGREN, J. et al. (2009), p. 172; ARNBJERG-NIELSEN, K.; FLEISCHER, H. S. (2009), p. 278.
82 Cf. EISENACK, K. et al. (2012), p. 458; TAYLOR; M. A. P.; PHILP; M. (2010), p. 71.
83 Cf. TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 171; TAYLOR; M. A. P.; PHILP; M. (2010), p. 74.
84 Cf. TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 142, 171; EISENACK, K. et al. (2012), p. 459; TAYLOR; M. A. P.; PHILP; M. (2010), p. 74.
85 Cf. ARKELL, B. P.; DARCH, G. J. C. (2006), p. 234.
86 Cf. LINDGREN, J. et al. (2009), p. 177; TAYLOR; M. A. P.; PHILP; M. (2010), p. 74.
87 Cf. STEWART, B. et al. (2011), p. 42f.
88 Cf. TAYLOR; M. A. P.; PHILP; M. (2010), p. 70.
89 Cf. TAYLOR; M. A. P.; PHILP; M. (2010), p. 71.

Analysing the category "Surveys, case studies etc.", the main strategic adaptation is tracking of climate change impacts as well as the costs of it.[90] Furthermore, a strategic planning for new facilities should be undertaken to minimise prospective risks.[91]

All in all, only a few strategies are given which contain best practise sharing, tracking of relevant information and deriving aspects for strategic future planning.

Barriers of implementation

Merely in four studies, implementation barriers for the logistics and transportation industry were identified (8 mentions). Either companies can cope with these barriers or it is too obvious for them to name it or they are not aware of potential problems in implementation. Nevertheless, some barriers were identified through LINDGREN, J. et al. (2009), REGMI, M. B.; HANAOKA, S. (2011), TAYLOR; M. A. P.; PHILP; M. (2010) and the TRANSPORTATION RESEARCH BOARD (2008). Barriers of implementation are financial restrictions of the company as well technological restriction in transportation.[92] LINDGREN, J. et al. (2009) point out that adaptation measures can affect each other. For example, falling trees through strong wind affect rail tracks and therefore their operations, but without trees the area is more vulnerable to fire as well as to rail buckling.[93] The TRANSPORTATION RESEARCH BROAD (Ed.) (2008) and TAYLOR; M. A. P.; PHILP; M. (2010) focus on resource constraints and the lack of relevant information which is important to make an effective adaptation to climate change impacts.[94] Moreover, communications barriers between stakeholders and the limitation of funding of planning and implementing of adaptation measures are identified.[95]

To sum up, only a few barriers are identified within the reference papers. Therefore, companies are not aware of them and they have no problems with adaptation implementation, respectively.

Open issues

15 main issues are identified from all 20 references. Seven mentions deal with the need of a risk analysis tool which can be integrated in the management tool for decision making.[96] Additionally, six mentions are about new design standard for infrastructures and transport facilities.[97] Other open issues with three mentions are the region specific research with risk and adaptation assessment[98], the identification of vulnerable locations[99], the need of a list with

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90 Cf. WALKER, L. et al. (2011), p. 12.
91 Cf. KIRSHEN, P. et al. (2008), p. 471.
92 Cf. REGMI, M. B.; HANAOKA, S. (2011), p. 29.
93 Cf. LINDGREN, J. et al. (2009), p. 176.
94 Cf. TRANSPORTATION RESEARCH BROAD (Ed.) (2008), p. 131; TAYLOR; M. A. P.; PHILP; M. (2010), p. 73.
95 Cf. TAYLOR; M. A. P.; PHILP; M. (2010), p. 73.
96 Cf. TRANSPORTATION RESEARCH BROAD (Ed.) (2008), p. 208; KOETSE, M. J.; RIETVELD, P. (2009), p. 209; GALLAGHER, T. L. (2009), p. 26; AREKELL, B. P.; DARCH, G. J. C. (2006), p. 236; LINDGREN, J. et al. (2009), p. 176; EISENACK, K. (2012), p. 460; STEWART, B. et al. (2011), p. 43.
97 Cf. SCHWARTZ, H. G. Jr. (2011), p. 8; GALLAGHER, T. L. (2009), p. 26; GARDINER, L. et al. (2008), p. 111; JONKEREN, O. (2009), p. 130; EISENACK, K. et al. (2012), p. 460; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 171.
98 Cf. REGMI, M. B.; HANAOKA, S. (2011), p. 39; GALLAGHER, T. L. (2009), p. 25; GARDINER, L. et al. (2008), p. 110.

weather impacts, risks and potential adaptation measures per transportation mode[100] and a tool for data-sharing and best practice[101], respectively. These are the most identified issues on this topic. Because of the inaccuracy of weather predictions, companies need a plan of all potential weather extremes with risks and adaptation measures as well as a cost calculation[102] per adaptation. Therefore, an extensive data basis is necessary. Monitoring and information systems[103] are needed to track current weather conditions and their direct impacts to every company. Moreover, TAYLOR; M. A. P.; PHILP; M. (2010) state that the Local Government should get more in charge for adaptation to the local climate change impacts.[104] Therefore, companies, government and sciences in business administration should focus on these issues to cope with them. Issues about technological aspects like new designs, improvements of drainage-systems[105], heat-resistant material[106] or improvement of efficiency of engines[107], should address the specific research field.

All in all, there are some open issues that are highly relevant in dealing with climate change impact, which should come into focus of the particular research field.

As it is shown above, a particular research issue is a region specific research as well as developing a list of potential risks and adaptation measure for this branch. The next chapter is focused on the model region Dresden and its logistics and transportation industry. The research is done by an interview analysis which is described shortly in the next chapter. Research questions are derived from the literature review and stated in the description of the analysis form.

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99 Cf. GALLAGHER, T. L. (2009), p. 27; GARDINER, L. et al. (2008), p. 81; KOETSE, M. J.; RIETVELD, P. (2009), p. 209.

100 Cf. PAPPIS, C. P. (2011), p. 111; STEWART, B. et al. (2011), p. 43; GALLAGHER, T. L. (2009), p. 25; TAYLOR; M. A. P.; PHILP; M. (2010), p. 76.

101 Cf. STEWART, B. et al. (2011), p. 43; GALLAGHER, T. L. (2009), p. 24; TRANSPORATION RESEARCH BOARD (Ed.) (2008), p. 208.

102 Cf. ARKELL, B. P.; DARCH, G. J. C. (2006), p. 235; WALKER, L. et al. (2011), p. 12.

103 Cf. EISENACK, K. et al. (2012), p. 460; TRANSPORTATION RESEARCH BROAD (Ed.) (2008), p. 208.

104 Cf. TAYLOR; M. A. P.; PHILP; M. (2010), p. 73.

105 Cf. PAPPIS, C. P. (2011), p. 112; SCHWARTZ, H. G. Jr. (2011), p. 8.

106 Cf. SCHWARTZ, H. G. Jr. (2011), p. 8; STEWART, B. et al. (2011), p. 43.

107 Cf. LOVE, G. et al. (2010), p. 137.

3 Interview analysis

In Chapter 2, a content analysis, step by step was given and applied on climate change impacts and adaptation measures in the logistics and transportation industry. Therefore some research gaps for this topic were identified. In this chapter, an introduction to the method of interview analysis as well as the tool called MAXQDA is drawn. Furthermore, the analysis is applied on the topic of this thesis.

3.1 Analysis methodology

Interview analysis is a qualitative and quantitative analysis of collected data through interviews which can cause the best-quality data because of the different perspectives of interviewees.[108] According to process of BURNARD, P. (1991) the steps of an interview analysis are similar to the process of a content analysis, which is explained and applied in Chapter 2. The aim is to gain a detailed assessment of issues which are addressed in an interview and to apply the gained data on a category system. Applying different persons' perspectives on one code system can cause problems in comparison. Also insufficient answers which are hardly answering the question can cause problems in the analysis. However, a systematic approach of analysis and an objective view of the analysis as well as quantitative date are the solutions for this problem.[109] According to MEUSER, M.; NAGEL, U. (1991), structured interviews have different functions. This type of interview is used to interview experts of on one specific aspect, to support the regard to the central topic of the interview. Moreover, the structured guideline makes interviews more comparable, because different perspectives of the interviewees were given. At least the structured interview serves as a reminder for the interviewer not to forget anything.[110] In the following the rough structured interview process is drawn in Table 4, which is processed on the basis of the approach of NOHL, A.-M. (2008):

Steps	NOHL, A.-M. (2008)
1.	Development of structured interview script.
2.	Identification of potential experts within the specific research field.
3.	Realization of structured interview and recording it.
4.	Transcription of the interview.
5.	Interpretation of the results.

Table 4: Interview analysis approach of NOHL, A.-M.
(Modelled after: NOHL, A.-M. p. 20-66.)

[108] Cf. EISIKOVITS, Z.; KOREN, C. (2010), p. 1642.
[109] Cf. BURNARD, P. (1991), p. 461f.
[110] Cf. MEUSER, M.; NAGEL, U. (1991), p. 445ff.

Furthermore, two different interpretations of structured interviews can be applied. Firstly, the formulating interpretation focus on time sequences, when the audio records are not transcribed. Tables with all relevant topics within the interviews, which are highly interesting for further research, occur.[111] Secondly, the reflective interpretation focuses on the approach of the processing of a specific topic.[112] Thereby it is divided in narratives, descriptions and argumentations. Narratives focus on actions with a time line. Descriptions are constant aspects which recur. Argumentations are reasons for own and strange actions.[113]

Within this thesis, a reflective interpretation is used to assess the interviews, because the aim is to show potential actions in case of climate change impacts. In the following the process which is shown above is applied.

First of all, research questions for this analysis are emerged from the research gaps of the literature review. Therefore, weather conditions and their potential risks to the model region Dresden and adaptation measures are in focus. Research is rarely done especially for logistics companies. In doing so the following research questions are derived.

1. ***What effect has climate change on the logistics and transportation industry in the model region Dresden?***
2. ***How do companies of the logistics and transportation industry adapt to climate change impacts?***
3. ***Are there any barriers for implementation for specific adaptation measures and a need for further research?***

The data collection was done through a structured interview which is derived from the research questions. The first part of the interview deals with weather extremes, i.e. heavy precipitation like rain and snow, storm, heat and cold waves and high radiation. Furthermore, every weather extreme is applied to the supply chain of the company, i. e. procurement, production, sales, disposal, research and development, logistic, employees and organisation, marketing and controlling. Therefore, it is possible to see where impacts occur. In the second part, the interviewees are asked about possible requests of their stakeholders such as customers, government or insurance agencies. The guideline for the interview is included in Appendix D. In the end, the interviewer refers to the profit and loss account as well as to the balance sheet to identify potential financial impacts through climate change. Furthermore, interviewees are asked for potential barriers of adaptation implementation and further adaptation measures for the whole branch.

The next step is the identification of potential interviewees. A request for participating in the interview about impacts of climate change to their companies is addressed to potential interviewees by an address list of the IHK[114]. Afterwards the participation of these companies is checked by telephone. Five individuals within the Dresden transportation providers are interviewed: one tour operator (company A), one company of road and rail transportation (compa-

[111] Cf. NOHL, A.-M. (2008), p. 46.
[112] Cf. NOHL, A.-M. (2008), p. 47.
[113] Cf. SCHÜTZE, F. (1987), p. 148, quoted after NOHL, A.-M. (2008), p. 48.
[114] Industrie- und Handelskammer.

ny B), two companies of road transportation (company C and D) and one company of air traffic (company E). Therefore, it is possible to capture views from different transportation modes and organisation. The interviews are recorded, transcribed and used to do a qualitative analysis with the QDA[115] software of MAXQDA.

3.2 MAXQDA – qualitative data analysis software

The systematic approach of a content analysis is easier to realize with a software tool. A lot of different tools were established over the last years.[116] AQUAD, ATLAS.ti, MAXQDA or NVIVO are examples for qualitative analysis tools.[117] These tools help to assess the collected data to the specific research questions efficiently. Within this paper MAXQDA was used, because it has a comprehensible desktop and works together with Microsoft-Excel. MAXQDA is used in several science fields like psychology, education science, criminology and business administration to analyse and evaluate text data. In MAXQDA a self-compiled code system is the basis for further data assessment. Text passages are assigned to these codes. Therefore a systematic assessment within all documents and all codes is possible and interpretations of the results can be made.[118] Table 5 describes the code system that emerged from the research questions which are stated above. The code system is partly analogical to the data extraction form of the literature review but leans on the structure of interview question as well. Additionally, to make an overall comparison of aspects in the literature and the current situation of logistics and transportation companies in the region of Dresden this approach was chosen. Sub-categories have the same definition as in the literature review in Chapter 2.

The code "Open issues" differs from the literature review. In this case, it is divided into three sub-categories. The structured interview focused on the different reasons for adaptation, but also on further undeveloped aspects for an appropriate adaptation. Therefore it asks for three criteria, "Stakeholder", "Research" and "Policy". Requests of stakeholders, which are coherent with climate change aspects, are assigned to the category "Stakeholder". Needs of further research in science, e.g. heat-resistant electronic components, were assigned to the category "Research". Moreover, adaptation measures which were implemented through political guidelines are assigned to the category "Political". This distinction supports the comprehension of different aspects which are made by the interviewees. Furthermore, adaptation measures and strategy are summarized in the code "Adaptation measures", because the questionnaire only asks for potential measures which a company might undertake. Additionally, the code "Risks" and "Opportunities" are divided in sub-categories the same as in the interview analysis.

All interview transcripts are uploaded in the MAXQDA software and analysed with the code system which is shown above. Identified text passages are assigned to the specific code. Thereby the analyst gets an overview about the amount of text passages per code as well as content of passages for the qualitative assessment.

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[115] Qualitative Data Analysis.
[116] Cf. MAYRING, P. (2010), p. 110.
[117] Cf. MAYRING, P. (2010), p. 112.
[118] For more information, please visit the website of MAXQDA (http://www.maxqda.de/produkte/maxqda).

Table 5: Code system for classifying the impacts and adaptation found in the interviews

1. Climate change impacts on company's operation	Yes		4. Opportunities	Competitive
	No			Financial
2. Weather condition	Change in precipitation pattern	Heavy snow		Physical
		Heavy rain		Regulatory
	Change in temperature	Heat waves	5. Adaptation measures	Technological
		Cold waves		Economic
	Storm and strong wind			Ecological
	Radiation			Social
3. Risks	Competitive			Political
	Financial		6. Barriers of implementation	Financial
	Physical			Physical
	Regulatory		7. Open issues	Stakeholders
				Research
				Policy

(Own illustration.)

4 Results

This part focuses on the qualitative assessment of the interview data which were identified through MAXQDA. Appendix E contains all relevant text passages with comments per code.

4.1 Assessment of applied codes

Climate change impacts on company's operation

The analysis shows that three of five companies has climate change impacts on their company. Companies A, B and E are aware of weather extremes and have adapted their operations to these extreme weather events (A, l. 9; B, l. 9; E, l. 17-18). Two of five companies recognised no climate change impacts on their operation. Company C and D do not associate extreme weather impact with climate change (C, l. 20; D, l. 20-21).

Extreme weather events

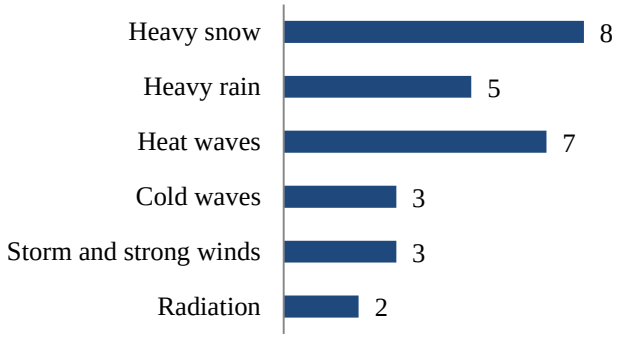


Figure 13: Number of identified weather conditions within the interviews (Own illustration.)

Weather extremes change from region to region. In the region of Dresden most weather extremes which affect the logistics and transportation industry are shown in Figure 13. In the winter time heavy snow (8 mentions) has the most impact. Heavy snow belongs to short run weather extremes. In this case, it has positive and negative impacts on a company's operation. Companies of road transportation have positive impacts, in the short run, as well as negative impacts, in the long run. The company of air traffic and the tour operator mention only negative impacts. Detailed information about these impacts is mentioned in the categories of "Risks" and "Opportunities".

In the summer time, heat waves (7 mentions) are the most influential weather extreme, which also belongs to the long run weather extremes. Companies B, C, and D as well as company A mention negative impacts through heat waves. Only company D stated one positive aspect related to this weather extreme. Its customers use its service more, because of cooled vehicles (D, l. 44). Heavy rain (5 mentions) is a short run weather extreme which leads to flooding in the long run. Both forms lead to negative impacts in operations of the tour operator and of road transportation. Only company C states one positive aspect through heavy rain which results in more trips (C, l. 109-110). This weather extreme induces no problems for the companies E and B. Storm and strong winds (3 mentions) are short run weather extreme as well.

Companies A, C and D suffer negative impacts through storms. Similar to heavy rain, storm and strong wind do not lead to impacts on the companies E and B. Fewer impacts are through cold waves and radiation. Cold waves (3 mentions), which is a long run impact, affect companies of road transportation. Other transportation modes and the tour operator suffer no impacts on their logistics and transportation operations. Furthermore, radiation (2 mentions) belongs to long run weather extremes. Company B and D mentioned negative impacts through it.

All in all, companies of road transportation have positive impacts through heavy snow, heavy rain and heat waves. The company of air traffic has only negative impacts through heavy snow and companies of rail and road transportation have only negative impacts through heat waves and radiation.

Risks through weather extremes

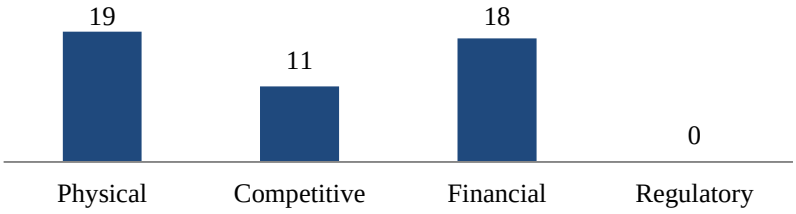


Figure 14: Number of identified of risks within the interviews (Own illustration.)

Altogether 48 risks were identified within the interviews. Company B and D state the most risks. The figure above shows the allocation of risks in physical, competitive, financial and regulatory risks. Physical, competitive and financial risks have nearly the same amount of mentions which shows that all aspects in a company are affected through extreme weather impacts. 19 physical risks are identified, because first impacts due to extreme weather patterns affect the vehicles. Most physical risks on transportation vehicles are through heavy snow. Heavy rain and heat waves have similar effects on transportation operations. Fewer impacts are through radiation and cold waves. Most impacts are on companies of road and rail transportation, because three companies of this mode were interviewed. Heavy snow has impacts on the business services of the travel operator due to flight cancellation (A, l. 67-69). Furthermore, snow leads to icing on trams which causes non-use of the vehicles and therefore to lost profit (B, l. 54). Heavy snow also results in higher effort in de-icing of runways and flight lines (E, l. 18) and it causes disruptions in the supply chain for car spare parts which are necessary for using the vehicles (D, l. 29). Heat waves also have high impact on logistics and transportation operations. Companies A, B and D state that extreme heat affects electronic equipment like air-conditioning systems (A, l. 41; D, l. 33) or navigation components on trams (B, l. 26-27), which lead to disruptions and to repair costs. Moreover, high temperatures affect drivers concentration (B, l. 42; C, l. 65-66) and trough usage of air-conditioning systems on hot days can cause driver illness which also lead to disruptions in operations (C, l. 66). Also cold waves have crucial impacts on electronic equipment, because they are stressed in starting for operating and starter batteries break down, as well as the recirculation pump,

which is necessary for car heating, cause faster illness of the drivers (D, l. 33). Furthermore, especially precipitation like heavy rain has effects on transport and logistics operations due to a long period, which causes flooding. River levels rise and roads are flooded. Blocked routes lead to disruptions in operations because of detouring (B, l. 114). Radiation has impacts on vehicles lack, which cause higher maintenance costs (B, l. 110; D, l. 138) and strong wind cause damage on vehicles if road signs fly against it (D, l.128-130). Companies of air traffic need to stop aircraft operations at a wind speed of 60-70 km/h, which causes flight cancellations (E, l. 31).

Disruptions in operations due to physical risks result in competitive risks. 11 competitive risks are identified. Suddenly heavy precipitations lead to high demand, which cannot be served through the transportation provider (C, l. 92), canceled river trips due to too high or too low water level (A, l. 97) and closed routes due to flooding which lead to detouring (D, l. 88) also cause customer dissatisfaction. This has crucial impact on profit of companies. Other competitive risks are caused by heavy snow. These are restrictions in services of the travel operator because of canceled flights due to airport closure (A, l. 71) and disruptions in maintenance equipment supply, e.g. de-icing agent for the airplanes (E, l. 25-27) which cause canceled flights as well. Extreme weather conditions lead to damage in the supply chain of different components. Impacts to the energy supply for computers (A, l. 97), which are highly necessary in every company, or the supply of equipment, which are needed in winter times to maintain its own operations (B, l. 128) are particularly serious. Strong winds also result in competitive risks. Company E needs to stop its check-in if wind is above a certain wind intensity (E, l. 18) and company D states impacts due to fallen trees which lead to detouring and time losses (D, l. 125-126). Not only impacts on vehicles affect transportation operations, but impacts on the driver are also very serious. Air moisture and radiation affect the health of drivers, which cause illness and fewer staff (D, l. 40-41).

Physical and competitive risks induce financial risks in the end, because damaged vehicles, lost trips and diseases of staff (C, l. 148) cause high costs (B, l. 118) and lost profit. Within the interviews 18 financial risks are identified. Company C states that due to high and low temperature and strong wind, people stay at home and do not use its service, which leads to lost profit (C, l. 36, 42, 44). Furthermore, disruptions in operations cause customer complaints (B, l. 51-52) and lead to lost profit. Moreover, rising costs due to investments in technological equipment, e.g. installation of more air-conditioning systems in working areas (A, l. 89), and in vehicles (B, l. 19) occur. Hence, energy and fuel consumption costs will rise because of more use of air-conditioning systems (A, l. 85) and through extreme weather vehicles use more fuel (D, l. 154). Furthermore, through losses of vehicles due to extreme weather conditions more vehicles (A, l. 89) and also operational material, e.g. more tires or tires with higher treads (D, l. 154), are needed, which leads to high investment costs. For the travel operator, costs increase for more drink water supply for employees and due to standby of buses, e.g. insurance and drivers, in cases of flight cancellation in winter times (A, l. 94-95). The company of air traffic states that especially due to heavy precipitation costs for dewatering and de-icing agent in winter time will incredibly increase (E, l. 60-61). Company D states that flooding has a critical impact on tourism and therefore leads to a profit decrease of 10-20 % (D, l.

91-92). In case of more extreme weather events higher maintenance cost and financial loses occur. No regulatory risks are identified within the interviews.

All in all, due to extreme weather events increasing costs occur in all transportation modes. Hence adaptation measures should be undertaken to minimise all costs (repair and maintenance costs).

Opportunities through weather extremes

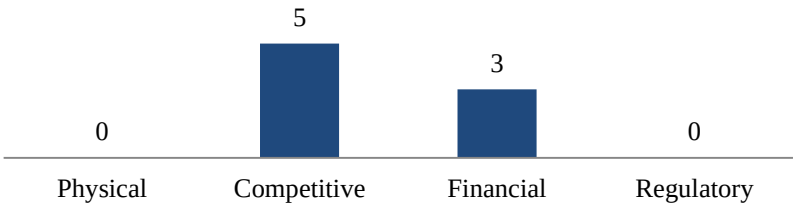


Figure 15: Number of identified opportunities within the interviews (Own illustration.)

Within the interviews eight opportunities are identified. With expectation of company B, all companies identify opportunities due to weather extremes. The division is shown in Figure 15.These opportunities are mostly competitive (5 mentions). Heavy precipitation has the most positive impact to transportation operations compared to other weather extremes. Due to rising temperatures, the travel time will shift from high season to low season. This leads to rising demand in off-season flights (A, l. 90-91). Company E also states, that bad weather conditions for inland holidays lead to higher demand of flights, because people want to spend their holidays in warm, sunny regions (E, l. 55). For road transportation providers a sudden appearance of heavy precipitation, e.g. snow or rain, results in higher demand of rides (C, l. 24), in the short run. After some days of same weather conditions, people can cope with the extreme by themselves (D, l. 45-46). Heat waves lead to the same result like heavy precipitation, because people want to sit in a vehicle, which protects passengers from weather extremes.

Furthermore, companies D and E mentioned some financial opportunities (3 mentions). Company D states that in general extreme weather conditions increase its profit due to more demand of its service in cases of heat waves or heavy precipitation (D, l. 165-166). Moreover, company E states some further financial opportunities. If the temperature in the winter time increases, company E will have a decrease in cost for de-icing agent for runways (E, l. 33). Additionally and due to bad weather conditions in autumn, winter and spring e.g. constant rain or long period of snow or low temperatures, the demand for flights increases, which induces higher profit (E, l. 43). Moreover, physical opportunities for better vehicle condition as well as regulatory opportunities for companies of the logistics and transportation industry in the region of Dresden are not identified.

To sum up, weather impacts can cause higher demand and lead to higher profit for companies of road transportation and air traffic.

Adaptation measures

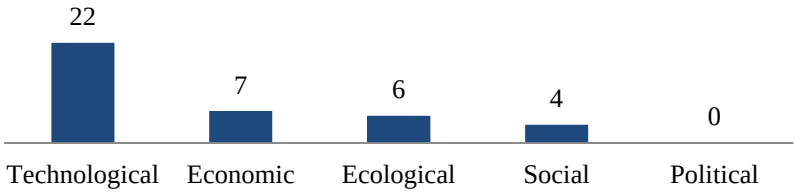


Figure 16: Number of identified adaptation measures within the interviews (Own illustration.)

Altogether 39 adaptation measures are identified within the interviews. To get a better overview of all adaptation measures, they are divided in five sub-categories, which are defined in Chapter 2. The division is shown in Figure 16. No adaptation measures through political guidelines are mentioned. The majority of measures are of technological nature (22 mentions), because vehicles, which are necessary for operations, are adapted to climate change impacts first. Most measures are undertaken due to extreme heat. Hence, installations of air-conditioning systems in vehicles for customers and drivers become necessary. Companies of road and rail transportation as well the travel operator made these adaptations due to heat waves (A, l. 41; B, l. 7; C, l. 49-50; D, l. 33). Additionally, the installation of window shades (A, l. 52-53) and tinted windows (B, l. 37; D, l. 148) helps to protect customers and employees from radiation and heat. Due to high energy costs for operating air-conditioning systems, company B uses hung windows in trams to circulate the air (B, l. 20-21). Other adaptation measures to protect the company operation against energy failure due to extreme heat are the installation of independent cooling systems and an emergency generator for IT (A, l. 51). Company E, the company of air traffic, extended its runway, because extreme heat affected the asphalt and deformed it (E, l. 31). In cases of heavy precipitation, drainage systems along the runway (E, l. 72-73) and routes (B, l. 65) as well as the water detention reservoir (E, l. 72-73) are installed and optimised. Furthermore, electronic components are optimised to be resistant against moisture (B, l. 60). Road salt and snow slides are stored for winter times (B, l. 132). In case of long periods of heavy snow, it is necessary to use cars with four-wheel drive (D, l. 78) in road transportation. High and low temperatures make installation of a good isolation of vehicles necessary. Company B installs wooden floors in trams to isolate them and therefore save costs in electricity (B, l. 23). Moreover, due to strong wind it is necessary to remove trees along the tram routes to protect the overhead cables from falling trees (B, l. 54).

Adaptations also have an economic character (7 mentions). A company undertakes such adaptation measures to offer superior service for their customers. Companies A, B and D mentioned different economic adaptations. Customer satisfaction rises, if the transportation of customers happens without any contact to weather (A, l. 39). Furthermore, by using a local weather situation system, employees can react fast to changed weather conditions (A, l. 71). In this case, a shift of transportation mode is useful to maintain operations and mitigate losses. Hence, more authority for decision making for employees is necessary in such situations (A, l. 111). Therefore, company A develops emergency scenarios to guide its employees (A, l. 97). Furthermore, sustainable constructions, which protect the transportation infrastructure for the

next years, are highly recommended (B, l. 116). Thus, companies can save money in the long run. Company D saves costs by using new winter tires every winter and keeping them on until late summer. Thus, summer tires are worn only for short periods of time, which saves costs. On the other hand, superior protection in winter is guaranteed by using new winter tires ever year (D, l. 76). Fewer disposals of old tires are environmentally friendly and save costs (D, l. 76). Moreover, company E learns from previous winter periods. The company extends its storage of de-icing agent to have no losses in winter times (E, l. 28-29).

A shift from gasoline to liquid gas (D, l. 31), the reduction of blank kilometre (D, l. 60), the installation of soot particle filters in cars (D, l. 62) and through cooperation of trams and big buses with taxis at night (D, l. 187) are ecological adaptation measures, which are mentioned six times within the interviews. Moreover, due to optimisation of drainage systems more waste water can be concentrated, which leads to less polluted waste water (E, l. 116).

Finally, four social adaptation measures are mentioned by companies A and B. These are related to employees, in priority, and to customers. Companies A and B state that air-conditioned working areas for employees are necessary to maintain the operation (A, l. 49; B, l. 7). Supply of drinking water in hot seasons is also useful to support the concentration ability of employees (A, l. 49). Moreover, employee trainings, for new and old employees, in extreme situations, e.g. maintenance in winter times (B, l. 128) is helpful for knowledge transfer. During extreme weather events, it is necessary to inform ones customers in order not to raise dissatisfaction. Company A develops information sheets about weather extremes and their risks on transportation vehicle (A, l. 83). Hence customers are not dissatisfied if such extremes occur.

All in all, all analysed transportation modes in the model region Dresden undertake adaptations to weather extremes to stable their operations. Especially, companies A and D have measures which go beyond the general aspect of technological adaptation.

Barriers of implementation

No barriers for further implementation of adaptation measures are identified. It is possible that the interviewees are not aware of potential implementation barriers or have not considered them within the interview.

Open issues

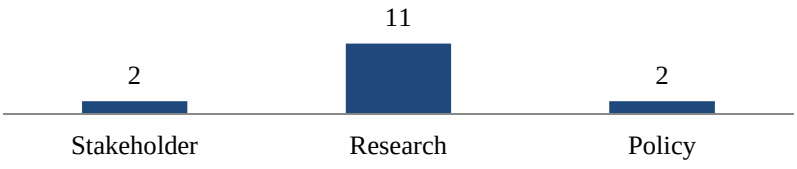


Figure 17: Number of identified open issues within the interviews (Own illustration.)

Altogether 15 open issues are identified within the interviews and shown in the figure above. The majority are identified in the category “Research” with 11 mentions. Company B, C and

D state several research issues to optimise the current stage of technology. Most mentions are from company B (9 mentions). These are further research in low energy consumption for air-conditioning (B, l. 19). Likewise, cooperation between vehicle users and production industry to generate optimal adaptations in vehicle construction and necessary components are supportive to identify the need of users (B, l. 32-33). Besides, company B considers heat and its impacts on material, e.g. asphalt, electronic components on the vehicles (B, l. 23) and change of material varnish from dark to light colors (B, l. 27). There is also a need for further research in vehicle isolation for summer and winter time as well as against high air moisture level in busses during summer times (B, l. 23). Company B also states, that light window glasses with a special filtering of radiation and heat are useful (B, l. 37). Moreover, the optimisation in tire treads for better grip on roads in winter times is another research issue (B, l. 73). Additionally, company C states a need of backseat-heating for their customers on cold days to make it more comfortable to travel (C, l. 57-60), as well as appropriate tires for all weather conditions (C, l. 87-88).

Open issues in the category "Stakeholders" are mentioned two times from company D. In road transportation services, customers request air-conditioned and tinted-window cars (D, l. 168). Customers want a comfortable ride in cases of extreme heat. Moreover, employees ask for an air-conditioned car to have a comfortable working area on the one hand and to be capable to offer good service for their customers on the other hand (D, l. 180-183). Open issues in the category "Policy" are stated by company D as well. The government should support small companies to extend their operations. This results from the high demand of transportation services in the region of Dresden, which current transportation providers cannot satisfy in peak times, i.e. the first day of heavy snow in the winter (D, l. 185). Moreover, cooperation between the public transportation providers and taxi companies should be implemented for night times when there is a little demand for public transportation (D, l. 187). This option will save costs.

To sum up, there is still a need for further research to optimise vehicles for transportation and to implement new strategies in further operations to minimise costs.

In the following, to summarise the found data within both analyses, a list of potential risks and adaptation measures for transportation providers within the model region Dresden is given.

4.2 List of potential risks and adaptation measures for model region Dresden

A list of adaptation measures which can be applied to climate change risks for the model region Dresden is given. In this connection, no adaptation measures due to sea level rise are included. Furthermore, the researcher limited the list only to important measures for the model region Dresden. General adaptation measures against climate change impacts, which can implement in every company and are not related to a specific extreme weather event, are shown in Table 6.

Table 6: General climate change adaptation measures

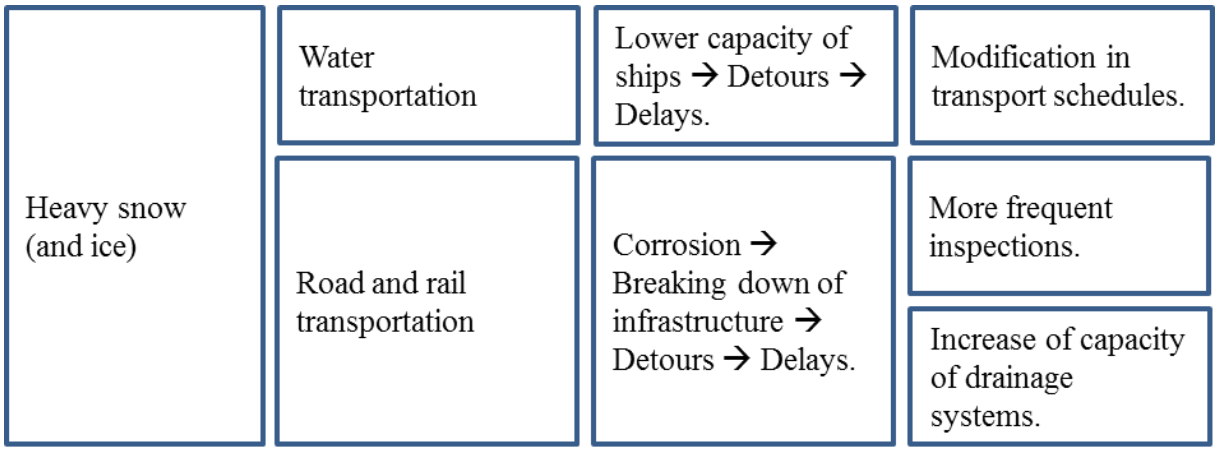
General adaptation measures	
Monitoring of impacts for fast reaction.	Formation of collaborations.
Involving of investments.	Strategic warning and information system.
Integration of impacts in risks management.	Developing of emergency scenarios.
Sharing of best practise.	Strategic planning for new facilities.
Enhancing of life-cycle cost of facilities.	Supply of drinking water for employees.
Identifying critical areas for further constructions.	Training of employees to maintain knowledge transfer; training of employees.
Communicating to customers in cases of weather extremes.	Workshop for assessing risks and adaptation measures to the company.
Analysing of potential synergies between company goals.	Integrating of stakeholders in strategic alignment.
Extending of storage for necessary equipment.	Concentrating of waste water → Generating of fewer unpolluted waste water.
Developing of information sheets for customers with necessary facts of weather extremes and company's operations.	

(Own illustration.)

Furthermore, Table 7 shows adaptation measures for potential extreme weather events and their risks separated by transportation mode. Column "Risk" includes impacts through the specific weather event and its further impacts on operation for the transportation mode.

Table 7: Potential weather extremes, impacts and adaptation per transportation mode

Potential weather extreme	Transportation mode	Risk	Adaptation measure
Heat waves	Air traffic	Buckling of runway → Delays → Flight cancellations.	Expansion of runways.
	Road transportation	Damage on health of customers and drivers.	Installation of air-conditioning systems.
	Rail transportation	Rail buckling → Blocked routes → Detours → Delays.	Use of heat resistant material by construction.
Storm and strong wind	Air traffic	Flight cancellation → Delays.	Sufficient runway capacity for various wind directions.
		Damage of facilities → Delays or Flight cancellation.	Hardening facilities for higher wind loads.
	Rail transportation	Blocked routes → Detours → Delays.	Establishment of tree-free zones in the railway corridor.
Flooding (through heavy rain)	Road and rail transportation	Blocked routes → Detours → Delays.	Implementation of dikes.
		Corrosion → Breaking down of infrastructure → Detours → Delays.	More frequent inspections.
			Increase of capacity of drainage systems.
	Rail transportation	Blocked routes → Detours → Delays.	Engines on both ends at a rail vehicle.



(Own illustration.)

4.3 Discussion of results

In both analyses numerous climate change impacts and adaptation measures were identified. Specific adaptation measures were found in the interview analysis and more general adaptation measures were identified in the literature review. Therefore, it is necessary to do a specific analysis per region as it is done in this thesis to gain specific impacts and adaptation measures. Only results of the literature review can answer the questions of potential adaptation implementation barriers. It is possible that the interviewees are not aware of potential implementation barriers yet. However, positive and negative impacts were identified within the interviews for nearly all transportation modes. Exceptions are the inland navigation and logistics companies, because no interviews were done. The company of rail transportation did not state positive impacts. Nevertheless, the results of the literature review show positive impacts through climate change for this transportation mode. However, climate change impacts lead to more negative impacts than positive ones which affect the operations of the transportation branch. Therefore, the costs of these companies will increase more than they decrease through potential opportunities. Similar adaptation measures were specified within both analyses. The companies of this branch of the model region Dresden undertake a lot of adaptation measures to stable their operations. Particularly in view of the fact that results of the literature review show, that there is a need in climate change adaptation for this branch. Compared to the results of the literature review, the results of the interviews analysis show similar aspects to this topic. It shows that companies do not need a specific phenomenon to adapt their operations. They make adaptations due to a current weather condition and its probability of appearance. Furthermore, more detailed adaptation measures were given within the interviews through experts.

Moreover, a structured interview is subjective and contains the bias of the interviewees. The aim is to exclude this bias. Still bias are in the analysis through answers the interviews were given. The different perception of the climate change definition of the interviewees influences the interview analysis. Therefore, two of five interviewees see no climate change impacts on their operation since the question deals with climate change. Nevertheless, the interview showed that also these two companies are exposed to weather impacts and they adapted their operations to it as well. Furthermore, not all modes of the logistics and transportation industry in the model region Dresden were interviewed. Therefore, the interview analysis deals with

references of this branch. The same aspect can be applied to the literature review because the results of the review are abandoned on the view of researcher. Within this thesis, different views of the authors within the adaptation measures and strategies were identified. So, monitoring of impacts can be a strategic tool and is therefore a strategy, but it is also possible that it is an action and therefore a measure, since information about climate change is tracked.

Methodological limitations within the literature review are of common nature, such as the availability of articles and studies as well as the search procedure and the selection of the articles. Furthermore, the small amount of interviews which do not cover all transportation modes in the model region Dresden limits the review as well. Therefore only an impression of potential adaptations and risks can be given. The applied framework for the literature as well as the interview analysis is nearly similar, to make the results more comparable. So it was necessary to apply found data to this framework. Through different views of interviews as well as authors, data can be interpreted in different ways which made it difficult to assign them to the codes. Therefore definitions of the different codes were made. Sometimes, there are overlappings of found data in the categories of adaptation measures, adaptation strategy and open issues within the literature review. This is the result of the publications range of eight years (2005 to 2012), because early identified issues are transposed over time. Hence, a shift from open issue to adaptation measures accrued.

4.4 Future view and recommendations

The interviewed companies of the model region Dresden already adapt their operations to climate change within their vehicles. One company undertakes actions to integrate its stakeholders in the operation. This is a good example for further adaptations in this field. It is necessary to integrate customers and inform them to mitigate dissatisfaction. Furthermore, best practice sharing is a good approach to deal with unexpected new circumstances, because it is possible that other companies has same problems and find already a solution. To stable the services especially in bad weather conditions, a weather track systems with a list of potential risks through this weather event and adaptation measures can help to react faster and save costs. Additionally, a list of scenarios for specific weather events should be developed to react fast as well.

Furthermore, further research on inland navigation on the river Elbe, in air traffic and logistic companies, which use trucks as well as trains, should be done to identify potential risks and adaptation measures within extreme weather events. These aspects were not considered within this thesis but are highly relevant for risks and adaptations of the whole industry.

5 Conclusion

This paper reviews climate change impacts and adaptation measures within the logistics and transportation industry. 20 references were identified and analysed. A data extraction form was developed and applied to extract relevant information. The current literature focuses more on general adaptation measures that can be implemented in corporate strategy than on specific adaptation measures for operation. However, to make an efficient climate change adaptation, reliable data is needed which should be available for every company of this branch and implemented in a company's strategy.

Most impacts of climate change were negative and have a crucial effect on a company's operations and in the end on its profit. Especially flooding and sea level rise were stated more often than other weather condition impacts in the literature. Furthermore, only a small part of literature dealt with regional analyses. Thus, a research gap of regional climate change impacts and adaptation is still open.

On this basis a questionnaire was developed. Five interviews were carried out with companies of rail and road transportation, air traffic and tour operation within the model region Dresden. These interviews were recorded and transcribed. Afterwards the transcriptions were analysed with the software of MAXQDA and assessed.

In the region of Dresden, heavy rain or snow for short periods of time may have positive effect on companies of road transportation. However, in the long run there are still negative effects for all companies. In general, these companies adapted their operations and their vehicles to possible climate change impacts. Most adaptation measures were of technological nature, because companies adapted their vehicles first, which are exposed to the weather extremes. No adaptation measures through political influence were identified. German government may not have developed sufficient guidelines for this topic yet. Since by now only little research had been carried out on regional adaptation opportunities, government can support companies in doing such analysis and developing a list with potential risks in order to develop adaptation measures. Companies could then react faster and save money. Government should support companies within the transportation sector with financial contribution or subsidies to implement more adaptation measures, because barriers of implementation have a financial nature particularly.

With data identified within the interviews and literature a list with potential risks and its adaptation operation was developed for the model region Dresden. However, more research should be done on the adaptation to climate change of logistics companies that handle freight transportation. In this thesis, the interviewed companies directly serve customers.

All in all, there is still a need for further research in the adaptation implementation process to minimise uncertainty in case of extreme weather events.

Appendix A: List of search terms

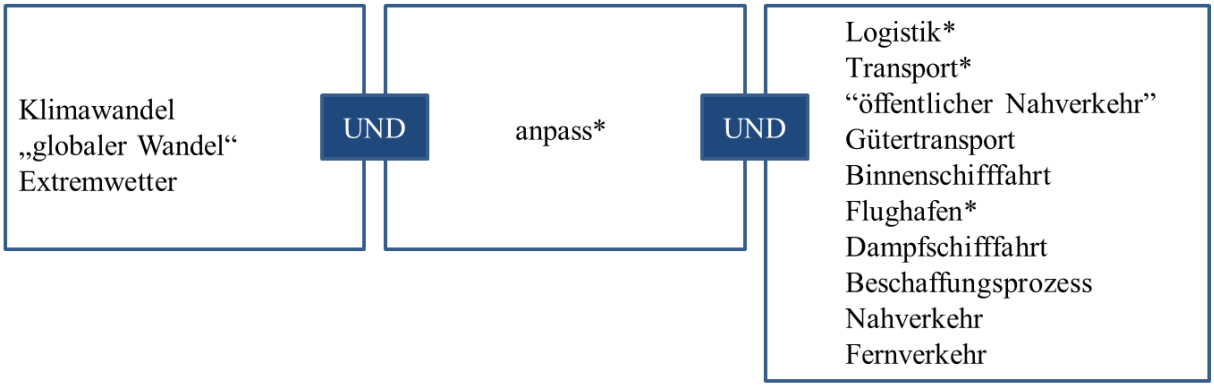


Figure 18: German search terms for literature research

(Own illustration.)

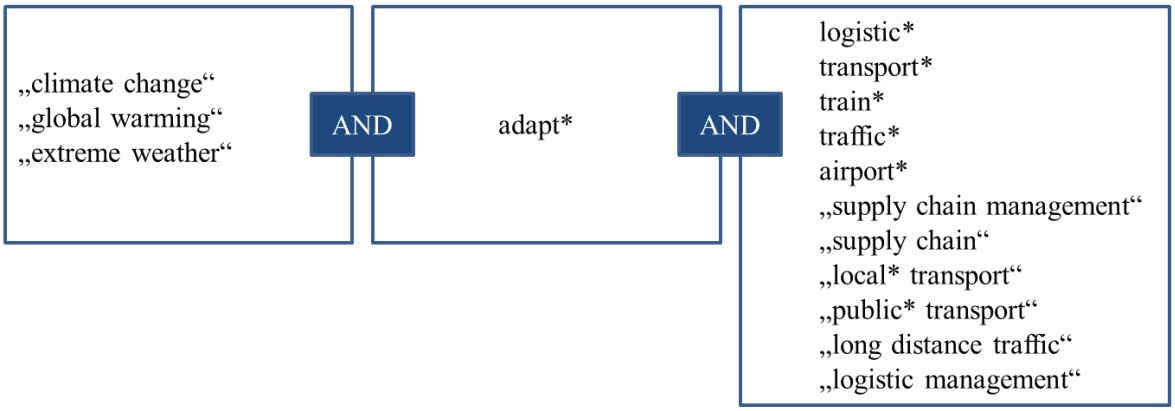


Figure 19: English search terms for literature research

(Own illustration.)

Appendix B: Documentation of research results

Database: EBSCO Host

Restriction: Business Source Complete, Academic Source Complete, EconLit with Full Text, E-Journals

Table 8: Research results of the EBSCO Host research

Search term: Abstract AND All Text AND Abstract				**Date**	**Hits**	**Relevant**	**Used**
"climate change"	AND	adapt*	AND logistic*	18.04.2012	49	0	0
"climate change"	AND	adapt*	AND traffic*	18.04.2012	22	0	0
"climate change"	AND	adapt*	AND train*	18.04.2012	93	0	0
"climate change"	AND	adapt*	AND "supply chain"	18.04.2012	19	0	0
"climate change"	AND	adapt*	AND transport*	18.04.2012	330	10	8
"global warming"	AND	adapt*	AND logistic*	18.04.2012	10	0	0
"global warming"	AND	adapt*	AND train*	18.04.2012	14	0	0
"global warming"	AND	adapt*	AND transport*	18.04.2012	96	3	2
"extreme weather"	AND	adapt*	AND logistic*	18.04.2012	3	0	0
"extreme weather"	AND	adapt*	AND transport*	18.04.2012	11	2	1
Total #1					647	15	11
Total #1 without redundant sources						7	7
Search term: Abstract AND All Text AND All Text				**Date**	**Hits**	**Relevant**	**Used**
"climate change"	AND	adapt*	AND "airport* management"	18.04.2012	4	0	0
"climate change"	AND	adapt*	AND "supply chain management"	18.04.2012	28	0	0
"climate change"	AND	adapt*	AND "local* transport"	18.04.2012	16	2	2
"climate change"	AND	adapt*	AND "public* transport"	18.04.2012	149	0	0
"global warming"	AND	adapt*	AND traffic*	18.04.2012	150	0	0
"global warming"	AND	adapt*	AND airport*	18.04.2012	69	0	0
"global warming"	AND	adapt*	AND "supply chain management"	18.04.2012	6	0	0
"global warming"	AND	adapt*	AND "supply chain"	18.04.2012	29	0	0
"global warming"	AND	adapt*	AND "local* transport"	18.04.2012	2	0	0
"global warming"	AND	adapt*	AND "public* transport"	18.04.2012	36	0	0
"extreme weather"	AND	adapt*	AND traffic*	18.04.2012	17	0	0
"extreme weather"	AND	adapt*	AND train*	18.04.2012	33	0	0
"extreme weather"	AND	adapt*	AND airport*	18.04.2012	14	0	0
"extreme weather"	AND	adapt*	AND "supply chain management"	18.04.2012	1	0	0
"extreme weather"	AND	adapt*	AND "supply chain"	18.04.2012	5	0	0
"extreme weather"	AND	adapt*	AND "local* transport"	18.04.2012	0	0	0
"extreme weather"	AND	adapt*	AND "public* transport"	18.04.2012	3	0	0
Total #2					562	2	2
Total #2 without redundant sources						2	2
TOTAL							9

(Own illustration.)

Database: WISO Wirtschaftswissenschaften

Restriction: Only "Wirtschaftswissenschaften"(Fachzeitschriften, Literaturnachweise)

Table 9: Results of the WISO research

Search term				Date	Hits	Relevant	Used
"climate change"	AND	adapt*	AND logistic*	17.04.2012	8	0	0
"climate change"	AND	adapt*	AND transport*	17.04.2012	60	1	1
"climate change"	AND	adapt*	AND traffic*	17.04.2012	3	0	0
"climate change"	AND	adapt*	AND train*	17.04.2012	22	0	0
"climate change"	AND	adapt*	AND airport*	17.04.2012	2	0	0
"climate change"	AND	adapt*	AND "supply chain management"	17.04.2012	2	0	0
"climate change"	AND	adapt*	AND "supply chain"	17.04.2012	5	0	0
"climate change"	AND	adapt*	AND "local* transport"	17.04.2012	0	0	0
"climate change"	AND	adapt*	AND "public* transport"	17.04.2012	3	0	0
"climate change"	AND	adapt*	AND "long distance traffic"	17.04.2012	0	0	0
"climate change"	AND	adapt*	AND "logistic* management"	17.04.2012	6	0	0
"global warming"	AND	adapt*	AND logistic*	17.04.2012	4	0	0
"global warming"	AND	adapt*	AND transport*	17.04.2012	17	0	0
"global warming"	AND	adapt*	AND traffic*	17.04.2012	3	0	0
"global warming"	AND	adapt*	AND train*	17.04.2012	11	0	0
"global warming"	AND	adapt*	AND airport*	17.04.2012	3	0	0
"global warming"	AND	adapt*	AND "supply chain management"	17.04.2012	3	1	1
"global warming"	AND	adapt*	AND "supply chain"	17.04.2012	6	1	1
"global warming"	AND	adapt*	AND "local* transport"	17.04.2012	0	0	0
"global warming"	AND	adapt*	AND "public* transport"	17.04.2012	1	0	0
"global warming"	AND	adapt*	AND "long distance traffic"	17.04.2012	0	0	0
"global warming"	AND	adapt*	AND "logistic* management"	17.04.2012	0	0	0
"extreme weather"	AND	adapt*	AND logistic*	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND transport*	02.06.2012	3	0	0
"extreme weather"	AND	adapt*	AND traffic*	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND train*	02.06.2012	2	0	0
"extreme weather"	AND	adapt*	AND airport*	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "supply chain management"	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "supply chain"	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "local* transport"	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "public* transport"	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "long distance traffic"	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "logistic* management"	02.06.2012	0	0	0
Total #1					164	3	3
Total #1 without redundant sources						2	2

Restriction: Only „Wirtschaftswissenschaften“ (Fachzeitschriften, Literaturnachweise, e-Books)

Search term					Date	Hits	Relevant	Used
Klimawandel	UND	anpass*	UND	Logistik*	03.06.2012	117	0	0
Klimawandel	UND	anpass*	UND	Transport*	03.06.2012	165	0	0
Klimawandel	UND	anpass*	UND	"öffentlicher Nahverkehr"	03.06.2012	3	0	0
Klimawandel	UND	anpass*	UND	Gütertransport	03.06.2012	10	0	0
Klimawandel	UND	anpass*	UND	Binnenschifffahrt	03.06.2012	6	0	0
Klimawandel	UND	anpass*	UND	Flughafen*	03.06.2012	30	0	0
Klimawandel	UND	anpass*	UND	Dampfschifffahrt	03.06.2012	0	0	0
Klimawandel	UND	anpass*	UND	Beschaffungsprozess	03.06.2012	3	0	0
Klimawandel	UND	anpass*	UND	Nahverkehr	03.06.2012	8	0	0
Klimawandel	UND	anpass*	UND	Fernverkehr	03.06.2012	2	0	0
"globaler Wandel"	UND	anpass*	UND	Logistik*	03.06.2012	2	0	0
"globaler Wandel"	UND	anpass*	UND	Transport*	03.06.2012	7	0	0
"globaler Wandel"	UND	anpass*	UND	"öffentlicher Nahverkehr"	03.06.2012	0	0	0
"globaler Wandel"	UND	anpass*	UND	Gütertransport	03.06.2012	1	0	0
"globaler Wandel"	UND	anpass*	UND	Binnenschifffahrt	03.06.2012	2	0	0
"globaler Wandel"	UND	anpass*	UND	Flughafen*	03.06.2012	0	0	0
"globaler Wandel"	UND	anpass*	UND	Dampfschifffahrt	03.06.2012	0	0	0
"globaler Wandel"	UND	anpass*	UND	Beschaffungsprozess	03.06.2012	0	0	0
"globaler Wandel"	UND	anpass*	UND	Nahverkehr	03.06.2012	0	0	0
"globaler Wandel"	UND	anpass*	UND	Fernverkehr	03.06.2012	0	0	0
Total #2						356	0	0
Total #2 without redundant sources							0	0
TOTAL								2

(Own illustration.)

Database: Web of Science

Table 10: Results of the Web of Science research

Search term: Topic	AND	Topic	AND Topic	Date	Hits	Relevant	Used
"climate change"	AND	adapt*	AND logistic*	17.04.2012	40	0	0
"climate change"	AND	adapt*	AND transport*	17.04.2012	15	1	1
"climate change"	AND	adapt*	AND traffic*	17.04.2012	46	1	1
"climate change"	AND	adapt*	AND train*	17.04.2012	2	0	0
"climate change"	AND	adapt*	AND airport*	17.04.2012	2	0	0
"climate change"	AND	adapt*	AND "supply chain management"	17.04.2012	11	0	0
"climate change"	AND	adapt*	AND "supply chain"	17.04.2012	1	0	0
"climate change"	AND	adapt*	AND "local* transport"	17.04.2012	4	0	0
"climate change"	AND	adapt*	AND "public* transport"	17.04.2012	200	3	3
"climate change"	AND	adapt*	AND "long distance traffic"	02.06.2012	0	0	0
"climate change"	AND	adapt*	AND "logistic* management"	02.06.2012	0	0	0
"global warming"	AND	adapt*	AND logistic*	17.04.2012	6	0	0
"global warming"	AND	adapt*	AND transport*	17.04.2012	1	0	0
"global warming"	AND	adapt*	AND traffic*	17.04.2012	4	0	0
"global warming"	AND	adapt*	AND train*	17.04.2012	1	0	0
"global warming"	AND	adapt*	AND airport*	17.04.2012	0	0	0
"global warming"	AND	adapt*	AND "supply chain management"	17.04.2012	3	0	0
"global warming"	AND	adapt*	AND "supply chain"	17.04.2012	0	0	0
"global warming"	AND	adapt*	AND "local* transport"	17.04.2012	0	0	0
"global warming"	AND	adapt*	AND "public* transport"	17.04.2012	46	2	2
"global warming"	AND	adapt*	AND "long distance traffic"	02.06.2012	0	0	0
"global warming"	AND	adapt*	AND "logistic* management"	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND logistic*	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND transport*	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND traffic*	02.06.2012	1	0	0
"extreme weather"	AND	adapt*	AND train*	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND airport*	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "supply chain management"	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "supply chain"	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "local* transport"	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "public* transport"	02.06.2012	7	2	2
"extreme weather"	AND	adapt*	AND "long distance traffic"	02.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "logistic* management"	02.06.2012	0	0	0
Total					390	9	9
Total without redundant sources						8	8

(Own illustration.)

Database: Emerald Management

Restriction: Journals

Table 11: Results of the Emerald Management research

Search term: Abstract AND All Fields AND All Fields				Date	Hits	Relevant	Used
"climate change"	AND	adapt*	AND transport*	17.04.2012	103	0	0
"climate change"	AND	adapt*	AND logistic*	17.04.2012	13	0	0
"climate change"	AND	adapt*	AND traffic*	17.04.2012	15	0	0
"climate change"	AND	adapt*	AND train*	17.04.2012	55	1	1
"climate change"	AND	adapt*	AND airport*	17.04.2012	7	0	0
"climate change"	AND	adapt*	AND "supply chain management"	17.04.2012	5	0	0
"climate change"	AND	adapt*	AND "supply chain"	17.04.2012	15	0	0
"climate change"	AND	adapt*	AND "local* transport"	17.04.2012	4	0	0
"climate change"	AND	adapt*	AND "public* transport"	17.04.2012	17	1	1
"global warming"	AND	adapt*	AND transport*	17.04.2012	15	0	0
"global warming"	AND	adapt*	AND logistic*	17.04.2012	6	0	0
"global warming"	AND	adapt*	AND traffic*	17.04.2012	4	0	0
"global warming"	AND	adapt*	AND train*	17.04.2012	12	0	0
"global warming"	AND	adapt*	AND airport*	17.04.2012	3	0	0
"global warming"	AND	adapt*	AND "supply chain management"	17.04.2012	5	0	0
"global warming"	AND	adapt*	AND "supply chain"	17.04.2012	5	0	0
"global warming"	AND	adapt*	AND "local* transport"	17.04.2012	0	0	0
"global warming"	AND	adapt*	AND "public* transport"	17.04.2012	1	0	0
"extreme weather"	AND	adapt*	AND transport*	03.06.2012	5	0	0
"extreme weather"	AND	adapt*	AND logistic*	03.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND traffic*	03.06.2012	1	0	0
"extreme weather"	AND	adapt*	AND train*	03.06.2012	2	0	0
"extreme weather"	AND	adapt*	AND airport*	03.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "supply chain management"	03.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "supply chain"	03.06.2012	4	0	0
"extreme weather"	AND	adapt*	AND "local* transport"	03.06.2012	0	0	0
"extreme weather"	AND	adapt*	AND "public* transport"	03.06.2012	0	0	0
Total					297	3	3
Total without redundant sources						1	1

(Own illustration.)

Database: RSWB Plus

Table 12: Results of the RSWB Plus research

Search term: (All Fields) AND (All Fields) AND (All Fields)	Date	Hits	Relevant	Used
("climate change") AND (adapt*) AND (logistic*)	18.04.2012	0	0	0
("climate change") AND (adapt*) AND (transport*)	18.04.2012	20	2	2
("global warming") AND (adapt*) AND (logistic*)	18.04.2012	0	0	0
("global warming") AND (adapt*) AND (transport*)	18.04.2012	3	1	1
("extreme weather") AND (adapt*) AND (logistic*)	18.04.2012	0	0	0
("extreme weather") AND (adapt*) AND (transport*)	18.04.2012	3	1	1
("globaler Wandel") UND (anpass*) UND (Logistik*)	18.04.2012	0	0	0
("globaler Wandel") UND (anpass*) UND (Transport*)	18.04.2012	0	0	0
(Extremwetter) UND (anpass*) UND (Logistik*)	18.04.2012	0	0	0
(Extremwetter) UND (anpass*) UND (Transport*)	18.04.2012	0	0	0
(Klimawandel) UND (anpass*) UND (Logistik*)	18.04.2012	0	0	0
(Klimawandel) UND (anpass*) UND (Transport*)	18.04.2012	3	0	0
Total		29	4	2
Total without redundant sources			2	2

(Own illustration.)

Database: ICONDA ICBlibrary

Table 13: Results of the ICONDA ICBlibrary

Search term	Date	Hits	Relevant	Used
("climate change") AND (adapt*) AND (logistic*)	18.04.2012	0	0	0
("climate change") AND (adapt*) AND (transport*)	18.04.2012	5	0	0
("global warming") AND (adapt*) AND (logistic*)	18.04.2012	0	0	0
("global warming") AND (adapt*) AND (transport*)	18.04.2012	0	0	0
("extreme weather") AND (adapt*) AND (logistic*)	18.04.2012	0	0	0
("extreme weather") AND (adapt*) AND (transport*)	18.04.2012	1	0	0
("globaler Wandel") UND (anpass*) UND (Logistik*)	18.04.2012	0	0	0
("globaler Wandel") UND (anpass*) UND (Transport*)	18.04.2012	0	0	0
(Extremwetter) UND (anpass*) UND (Logistik*)	18.04.2012	0	0	0
(Extremwetter) UND (anpass*) UND (Transport*)	18.04.2012	0	0	0
(Klimawandel) UND (anpass*) UND (Logistik*)	18.04.2012	0	0	0
(Klimawandel) UND (anpass*) UND (Transport*)	18.04.2012	0	0	0
Total		6	0	0
Total without redundant sources			0	0

(Own illustration.)

Database: Google Scholar

Restriction:
Subject area: Business, Administration, Finance and Economics
Where my words occur: anywhere in the article
Return articles published between: 2007

Table 14: Results of Google Scholar research

Search term	Date	Hits	Relevant	Used
AND adapt * AND logistic * "climate change" -mitigation -production	23.04.2012	132	0	0
AND adapt * AND transport* "climate change" -mitigation -production	23.04.2012	444	2	2
AND adapt * AND transport * "global warming" -mitigation -production	24.04.2012	53	0	0
"global warming" AND adapt* AND transport	24.04.2012	189	0	0
"globaler Wandel" AND anpass* AND Logistik*	18.04.2012	0	0	0
"globaler Wandel" AND anpass* AND Transport*	18.04.2012	4	0	0
Total		822	2	2
Total without redundant sources			2	2

(Own illustration.)

Database: Sächsische Landes- und Universitätsbibliothek

Manual research
Date: 02.06.2012

Table 15: Results of manual research in the stock of SLUB

Journal	Searched years	Used
International Journal of Logistics Management	2007 - 2012	0
Logistik Heute	2007 -2012	0
Logistics Spectrum	2007 - 2010	0
Transportation	2007 - 2012	1
Transportation Research Part D: Transport and Environment	2007 - 2012	1
Transportation Research Part E: Logistics and Transportation Review	2007 - 2012	0
Transportation Science	2007-2009, 2011-2012	0
Journal of Business Logistics	via EBSCO Host search	0
Transport Logistics	via EBSCO Host search	0
Total sources		2
	Both sources already found in electronical database.	

(Own illustration.)

Appendix C: Data extraction forms

Table 16: Data extraction form of ARKELL, B. P.; DARCH, G. J. C. (2006)

1. Title		**Impact of climate change on London's transport network**
2. Author		ARKELL, B. P.; DARCH, G. J. C.
3. Publication year		2006
4. Country of origin		United Kingdom
5. Publication type		Journal
6. Source		Proceedings of the ICE - Municipal Engineer, Vol. 159, Issue 4, p. 231 –237
7. ISI-impact factor		-
8. Database		- EBSCO Host: Business Source Complete, Academic Source Complete, Econ-Lit with Full Text, E-Journals - Web of Science: - RSWB Plus
9. Search term		*EBSCO Host:* "climate change" AND adapt* AND transport* "global warming" AND adapt* AND transport* "extreme weather" AND adapt* AND transport* *Web of Science:* "global warming" AND adapt* AND transport* *RSWB Plus:* ("climate change") AND (adapt*) AND (transport*) ("global warming") AND (adapt*) AND (transport*) ("extreme weather") AND (adapt*) AND (transport*)
10. Paper type		Empirical
11. Paper method		Case study
12. Geographical region		Local (London)
13. Research period		2004 - 2005 (p. 234)
14. Transportation mode		Rail transportation Road transportation
15. Weather condition	**Short run**	- heavy rain (p. 233) - storms (p. 233)
	Long run	- flooding (p. 233) - heat waves (p. 233) - drought (p. 233) - sea level rise (p. 233)
16. Risks	***Literature review***	- tidal and river flooding affecting new infrastructure in the Thames Gateway (p. 233) - local flooding of London Underground, rail and road infrastructure, including station closures (p. 233) - damage to national rail and road infrastructure from hot weather (p. 233) - passenger comfort on London Underground in hot weather (p. 233)

16. Risks	***Survey, interviews, case study***	- affecting access and egress from stations, potentially stranding or disabling the system (p. 233) - passenger dissatisfaction is likely to increase (p. 233) - switching between modes (rail to road) increase of air pollution (p. 233) - restricted capacity of storm drainage systems (p. 234) - buckled rails through high temperatures (p. 234) - speed restrictions (p. 234) - shrinkage and expansion effects of the London clays on underground services → increasing road repairs (costs) (p.235) - inadequate ventilation system for cooling the Underground (p.235) - overcrowding and failed or delayed services (p. 235)
17. Opportunities	***Literature review***	-
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	-
	Survey, interviews, etc.	- flood proofing in high risk areas (e.g. use of flood boards and switch gear, substations) (p. 233) - construction of higher capacity drains (p. 234) - better drain maintenance, flood warning (p. 234) - construction and operation of barriers to prevent water ingress to stations (p. 234) - better information on flooding to transport users (p. 234) - plans to enhance capacity (more frequent trains) (p. 235) - new ventilation capacity with fan and local cooling systems (p. 236) - detailed, strategic monitoring programme of temperature and humidity in the Underground (in train and stations) (p. 237)
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	- building the most vulnerable infrastructure away from the river edge or above extreme flood levels (p. 233) - incorporating climate change risks into routine risk management procedures to help prepare for future adverseevents (p. 236) - decision-makers should ensure, that climate risk management measures are sufficiently flexible and schemes can be adapted if necessary (p. 236) - new infrastructure projects (such as storm drainage) should include a reasonable allowance for climate change risks (p. 236) - design new infrastructure, rolling stock and vehicles for the climate throughout their design life (p. 237)
20. Barriers of implementation		-
21. Open research issues		- quantification of improved standards (p. 235) - examine behavioural response of passengers to higher temperatures, including identification of the costs and benefits of adaptation measures (e.g. air conditioning) (p. 236)
21. Open research issues		- identification of the potential risks to transport modes (e.g. a switch from the Underground to buses) may be triggered (p. 236)
22. Remarks		-

(Own illustration.)

Table 17: Data extraction form of HAWKES, P. et al.(2010)

1. Title		**Impacts of climate change on waterborne transport**
2. Author		HAWKES, P.; PAULI, G.; MOSER, H.; ARNTSEN, Ø.; GAUFRES, P.; MAI, S.; WHITE, K.
3. Publication year		2010
4. Country of origin		United Kingdom
5. Publication type		Journal
6. Source		Journal of Civil Engineering 163, p. 55–63, (special issue on Water Transport, Institution of Civil Engineers)
7. ISI-impact factor		0.162
8. Database		- EBSCO Host: Business Source Complete, Academic Source Complete, Econ-Lit with Full Text, E-Journals - Web of Science - RSWB Plus
9. Search term		*EBSCO Host:* "climate change" AND adapt* AND transport* *Web of Science:* "climate change" AND adapt* AND transport* *RSWB Plus:* ("climate change") AND (adapt*) AND (transport*)
10. Paper type		Empirical
11. Paper method		Content analysis
12. Geographical region		Global
13. Research period		-
14. Transportation mode		Water transportation
15. Weather condition	**Short run**	- storm (p. 59) - big waves (storm surges) (p. 59)
	Long run	- rising groundwater (p. 59) - changes in water temperature (p. 59) - drought (p. 59) - flooding (p. 59) - changes precipitation (p. 59)
16. Risks	***Literature review***	- effects on manoeuvrability and operational efficiency of navigation structures (loadings different from design loading, affecting stability and resiliency) (p. 59) - higher water levels - modifications to existing ports and mooring areas or reduce their potential for expansion (p. 59) - reducing the depth of water availability for navigation and for human activities associated with ports (p. 59) - disrupting navigation through increase in the frequency of high flow, high water level and flooding during winter → increased downtime and risk of damage to vessels (p. 61)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	- in Germany, decreased duration of ice cover may be beneficial - resulting in extended navigation seasons (p. 60) - inland navigation to benefit from climate change policy, as a low-emissions alternative to road and rail freight (p. 61) - shift from rail and road to inland navigation (p. 62)
	Survey, interviews, etc.	-

18. Adaptation measures	***Literature review***	- monitoring and preparedness to respond to impacts (p. 61)
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	- considering in future planning but navigation does not immediately need to be concerned about climate change (p. 63)
	Survey, interviews, etc.	-
20. Barriers of implementation		-
21. Open research issues		-
22. Remarks		-

(Own illustration.)

Table 18: Data extraction form of POWSE, T. D. et al. (2009)

1. Title		**Implications of climate change for economic development in Northern Canada: Energy, resource, and transportation sectors**
2. Author		PROWSE, T. D.; FURGAL, C.; CHOUINARD, R.; MELLING, H.; MILBURN, D.; SMITH, S. L.
3. Publication year		2009
4. Country of origin		Sweden
5. Publication type		Journal
6. Source		AMBIO: A Journal of the Human Environment, Vol. 38, Issue 5, p. 272-281
7. ISI-impact factor		1.705
8. Database		Web of Science
9. Search term		climate change AND adapt* AND transport*
10. Paper type		Empirical
11. Paper method		Content analysis
12. Geographical region		Global (Canada)
13. Research period		-
14. Transportation mode		Water transportation Road transportation
15. Weather condition	**Short run**	-
	Long run	- increase in temperature (p. 277)
16. Risks	***Literature review***	- reductions in ice thickness associated with climate warming → reduction in maximum loads → unsafely transport (p. 278) - large investments in land-based roads might be the only viable, long-term adaptation approach (p. 279)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	- expanding of potential period of operation for inland navigation through an increase in the river ice-free season as a result of climate warming (p. 277)
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	- modifications in ice-road construction (p. 278) - modification in transport schedules to concentrate shipping into the core portion of the winter when ice thickness is maximized (p. 278)
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	-
20. Barriers of implementation		-
21. Open research issues		-
22. Remarks		-

(Own illustration.)

Table 19: Data extraction form of SUAREZ, P. et al. (2005)

1. Title		**Impacts of flooding and climate change on urban transportation: A systemwide performance assessment of the Boston Metro area**
2. Author		SUAREZ, P.; ANDERSON, W.; MAHAL, V.; LAKSHMANAN, T.R.
3. Publication year		2005
4. Country of origin		USA
5. Publication type		Journal
6. Source		Transportation Research Part D, Vol. 10, Issue 3, p. 231–244
7. ISI-impact factor		-
8. Database		- EBSCO Host: Business Source Complete, Academic -Source Complete, EconLit with Full Text, E-Journals - Web of Science
9. Search term		*EBSCO Host:* "climate change" AND adapt* AND transport* "global warming" AND adapt* AND transport* *Web of Science:* "global warming" AND adapt* AND transport*
10. Paper type		Empirical
11. Paper method		Case study
12. Geographical region		Local (Boston)
13. Research period		-
14. Transportation mode		Rail transportation
15. Weather condition	**Short run**	- storm (p. 232) - intensive precipitation (p. 233)
	Long run	- flooding (p. 232) - sea level rise (p. 232)
16. Risks	***Literature review***	- doubling in delays and lost trips (p. 231) - cancelling of trips because either the origin location or the destination location is flooded (p. 234) - longer travel time (p. 234) - disruptions are economic costs (lost work-days, lost sales, or lost production) (p. 234)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	-
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	-
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	-
20. Barriers of implementation		-
21. Open research issues		-
22. Remarks		-

(Own illustration.)

Table 20: Data extraction form of LINDGREN, J. (2009)

1. Title		**Climate adaptation of railways: Lessons from Sweden**
2. Author		LINDGREN, J.; JONSSON, D. K.; CARLSSON-KANYAMA, A.
3. Publication year		2009
4. Country of origin		Sweden
5. Publication type		Journal
6. Source		European Journal of Transport and Infrastructure Research, Vol. 9, Issue 2, p. 164-181
7. ISI-impact factor		-
8. Database		Web of Science
9. Search term		climate change AND adapt* AND traffic*
10. Paper type		Empirical
11. Paper method		Case study
12. Geographical region		Global
13. Research period		-
14. Transportation mode		Rail transportation
15. Weather condition	**Short run**	- storm (p. 169, 171) - intensive precipitation (p. 171)
	Long run	- temperature extremes (p. 168, 171) - increased rainfall (change in precipitation) (p. 168) - permafrost (p. 168) - flooding (p. 169, 171) - snow and ice (p. 171)
16. Risks	***Literature review***	- India: through heavy rainfall lead to subsequent landslides (p. 169) - UK: rail buckling due to high summer temperatures (p. 169)
16. Risks	***Survey, interviews, etc.***	- disturbances after technical failures (p. 171) - minor disturbances and delays in traffic in wintertime (p. 171) - low physical flexibility in the event of disturbances (p. 171) - disturbances in the power supply from external networks directly influence the functionality of the railway transport system (p. 171) - initial ground conditions affect the failures in the drainage system (p. 171) - movements in the ground trigger rail buckling incidents (p. 172) - tree-free zones around the tracks lead to vulnerability to heat and temperature variations as well as to vulnerability to high wind speeds (p. 172) - already reaching of limitation in cooling the electric equipment (p. 172) - disturbances leading to decreased capacity and complete stops (p. 172) - extreme events creating system breakdowns and severe accidents (p 172) - very dry conditions followed by intensive precipitation might lead to break-down of the drainage system (p. 172) - effecting of ground stability through flooding (p. 175)
17. Opport-unities	***Literature review***	- warming will provide a modest benefit for Canadian rail infrastructure, except in regions underlain by permafrost (p. 168)
	Survey, interviews, etc.	- milder winter will lead to fewer problems with track switches, train set doors and train engines (p. 172)

18. Adaptation measures	***Literature review***	-
	Survey, interviews, etc.	- fans for cooling electrical equipment during periods of extreme heat (p. 172) - warning systems along the highest priority tracks (p. 172) - establishment of tree-free zones in the railway corridor for high priority parts of the network (p. 173) - optimisation of drainage system (p. 173) - updating of all drainage culverts to withstand increased loads of traffic on some prioritised tracks (p. 173) - temperature maps for neutral temperatures have been updated (p. 173) - systematic mapping of climate-related vulnerabilities and threats to the system (p. 176)
19. Adaptation strategy	***Literature review***	Europe: - systematic mapping of different types of climate threats, vulnerabilities and their consequences (p. 177) - consideration of climate change in the early stages of the planning process; risk and vulnerability analysis methods that are used in the planning process (p. 177) - explorative, future-orientated tools should be included; scenarios, back-casting and expert opinion workshops for assessing future threats and evaluating adaptation measures (p. 177) - possibility of creating synergies with climate mitigation goals and other environmental goals should be investigated and exploited (p. 177)
	Survey, interviews, etc.	-
20. Barriers of implementation		- measures to reduce the vulnerability to falling trees and reduction of vulnerability to fires or rail buckling may be counter-productive (p. 176)
21. Open research issues		- climate change impacts in the risk and vulnerability analysis methods of companies (p. 176)
22. Remarks		- literature review has a global scope (USA, Canada, India, Qinghai-Tibet Railway, UK) - conclusion of European Railway

(Own illustration.)

Table 21: Data extraction form of WALKER, L. et al. (2011)

1. Title		**Identifying surface transportation vulnerabilities and risk assessment opportunities under climate change case study in Portland, Oregon**
2. Author		WALKER, L.; FIGLIOZZI, M. A.; HAIRE, A. R.; MACARTHUR, J.
3. Publication year		2011
4. Country of origin		USA
5. Publication type		Record
6. Source		Forthcoming 2011 Transportation Research Record
7. ISI-impact factor		-
8. Database		Web of Science
9. Search term		"climate change" AND adapt* AND transport* "climate change" AND adapt* AND train*
10. Paper type		Empirical
11. Paper method		Case Study
12. Geographical region		Local (Portland)
13. Research period		2009/ 2010 (survey) (p. 6)
14. Transportation mode		Rail Transportation Road Transportation
15. Weather condition	**Short run**	- intensive precipitation (p. 6) - storm (p. 7)
	Long run	- flooding (p. 5)
16. Risks	***Literature review***	-
	Survey, interviews, etc.	- travel delay and the resulting closure of two major roads (p. 5) - tremendous damage on roadway structures through flooding (p. 6)
17. Opportunities	***Literature review***	-
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	-
	Survey, interviews, etc.	- light rail vehicles with engines on both ends thus operating in either direction (p. 10) - assessing of availability of typically nearby alternative routes (local streets) (p. 10)
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	- improvements of height of sea walls, landslide fencing and monitoring (p. 11) - disuse of the facility may be the most cost-effective solution e.g. closure of landslide-prone facilities (p. 11) - advanced analysis tools for potential traffic delay, detour effects, and to estimate potential economic impacts of climate change impacts (p. 12) - tracking of costs through climate change (p. 12)
20. Barriers of implementation		-
21. Open research issues		-
22. Remarks		-

(Own illustration.)

Table 22: Data extraction form of REGMI, M. B.; HANAOKA, S. (2011)

1. Title		**A survey on impacts of climate change on road transport infrastructure and adaptation strategies in Asia**
2. Author		REGMI, M. B.; HANAOKA, S.
3. Publication year		2011
4. Country of origin		Thailand
5. Publication type		Journal
6. Source		Environmental Economics and Policy Studies, Vol. 13, Issue 1, p. 21–41
7. ISI-impact factor		-
8. Database		EBSCO Host: Business Source Complete, Academic Source Complete, EconLit with Full Text, E-Journals
9. Search term		climate change AND adapt* AND transport*
10. Paper type		Empirical
11. Paper method		Case study
12. Geographical region		Global (Asia)
13. Research period		June – July 2009 (survey) (p. 30)
14. Transportation mode		Road transportation
15. Weather condition	**Short run**	- heavy rainfall (p. 25) - storm (p. 25)
	Long run	- snow (p. 25) - sea level rise (p. 25) - increases in temperature (p. 25) - flooding (p. 35)
16. Risks	***Literature review***	- damage to the transportation sector therefore rising infrastructure costs (p. 25) - traffic disruption (p. 25) - thermal expansion of bridge joints, the liquidation of asphalt pavements and increased maintenance of pavement (p. 26) - overflow of side drains and cross drainage works (p. 26) - submersion of bridges and inundation of coastal roads cause to road closures due to landslides (p. 26) - buckling of joints of steel structure (p. 26) - operation and maintenance costs will increase thus costs of salts for snow melting (p. 26) - affecting of drainage, road pavement, driving condition and visibility, affect bridges and culverts waterways and clearance (p. 26) - adopting higher design standards for costly infrastructure (p. 28)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	-
	Survey, interviews, etc.	-

18. Adaptation measures	***Literature review***	- integration of climate adaptation as a general risk management issue (p. 27) - increasing in design parameters for designing bridges, culverts, and drains (p. 28) - high and strengthened side barriers (p. 28)
	Survey, interviews, etc.	- more frequent inspection of drainage systems, road signs and steel bridges for corrosion (p. 34) - installation of additional warning information boards and signs (p. 34) - assessing of technical and economic viability as well as life-cycle costing (p. 34) - consideration of likely impacts of climate change in planning of future transportation track extension (p. 38) - evaluation of availability of less vulnerable routes (p. 29)
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	-
20. Barriers of implementation		- financial and technological barriers (p. 29)
21. Open research issues		- need of adequate policy and design guidelines to consider the impacts of predicted climate events (p. 27) - extension of laws, rules and guidelines related to environmental issues (p. 36) - country-specific assessment and quantification of impacts and adaptation strategies (p. 39)
22. Remarks		-

(Own illustration.)

Table 23: Data extraction form of GALLAGHER, T. L. (2009)

1. Title	**Transportation study urges climate adaptation**
2. Author	GALLAGHER, T. L.
3. Publication year	2009
4. Country of origin	USA
5. Publication type	White paper
6. Source	Bipartisan Policy Center, Washington, D.C.
7. ISI-impact factor	-
8. Database	EBSCO Host: Business Source Complete, Academic Source Complete, EconLit with Full Text, E-Journals
9. Search term	"climate change" AND adapt* AND transport*
10. Paper type	Empirical
11. Paper method	Content analysis
12. Geographical region	Global (USA)
13. Research period	-
14. Transportation mode	Road transportation Rail transportation Water transportation Airport

15. Weather condition	**Short run**	- heavy rainfall (p. 20)
	Long run	- increase in temperature (p. 16) - sea-level rise (p. 17) - changes in precipitation (p. 17) - permafrost (p. 17) - flooding (p. 20)
16. Risks	***Literature review***	- reduction in water depth cause to "light loading" thus resulting in economic impacts (p. 16) - increased inundation of coastal infrastructure (p. 18) - underground transit facilities are particularly vulnerable to flooding where ventilation openings and other access points are not sufficiently elevated (p. 18) - affecting of low bridges (p. 18) - highways ramps are underwater case to loose of highway functionality (p. 19) - permanent damage, destroying of bridges and pavement (p. 19) - damage to signage and overhead cables and disruption of roadway operations through downed trees and debris (p. 20) - drought and flood conditions can stop barge traffic on the river system therefore agricultural products cannot move from the interior to market (p. 21) - delays in the air travel system at airports where runway length is not sufficient to compensate for decreased lift for aircraft on hot days (p. 21) - increase in cost through energy consumption, for refrigerated cargo transport and transit systems (p. 21) - increase in maintenance and repair costs (p. 22)
	Survey, interviews, etc.	-
17. Opport-unities	***Literature review***	Warmer winter: - reduction of delays (p. 16) - improve ground and air transportation reliability (p. 16) - decrease the need for road maintenance therefore saving costs (p.16) - reduction in ice cover on the inland waterway system therefore increasing the shipping season (p. 21)
	Survey, interviews, etc.	-
18. Adaptation Measures	***Literature review***	- changes in design and materials (revision of design standards) (p. 24) - avoiding climate change vulnerable areas (p. 24) - developing alternate routes or services to maintain continuity of travel (p. 24)
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	- changes in policies and practices designed to deal with climate threats and risks (p.23) - including of extreme weather events into routine operations (p.23) - improving collaboration with weather and emergency management (p. 23) - sharing best practices of agencies and transportation providers (p. 24) - implications for emergency management (p. 20) - introducing risk assessment and vulnerability analyses (p. 24) - strategies focus on reducing the exposure of infrastructure by moving service to lower-risk areas (p. 24/25)
	Survey, interviews, etc.	-
20. Barriers of implementation		-

21. Open research issues	- need for adaptation planning at the national, state, and local levels to address the potential impacts of climate change (p. 25) - need for decision support tools to support the planning process, risk assessment tools and adaptive management approaches (p. 26) - development of new design standards for pavement, bridges etc. (p. 26) - identifying vulnerable locations → minimise future risks (p. 27)
22. Remarks	-

(Own illustration.)

Table 24: Data extraction form of JONKEREN, O. (2009)

1. Title		**Adaptation to climate change in inland waterway transport**
2. Author		JONKEREN, O.
3. Publication year		2009
4. Country of origin		Netherlands
5. Publication type		Book
6. Source		Thela Thesis, Tinbergen Institute research series ; 460, Research series / Universiteit van Amsterdam. - VIII, 153 S.; graph. Darst. Zugl.: Amsterdam, Vrije Univ., Diss.
7. ISI-impact factor		-
8. Database		WISO Wirtschaftsdatenbank
9. Search term		"climate change" AND adapt* AND transport*
10. Paper type		Empirical
11. Paper method		Scenario analysis and content analysis
12. Geographical region		Global
13. Research period		January 2003 until July 2003 for Rhine case study (p. 22)
14. Transportation mode		Water transportation
15. Weather condition	**Short run**	-
	Long run	- increase in temperatures (p.11)
16. Risks	***Literature review***	- low water levels imply restrictions on the load factor of inland ships which cause to economic consequences (p. 12) - increase of days with high water levels in winter implies an increase in the number of days on which inland waterway transport is blocked for safety reasons (p. 12) - reduction in load factor for inland ships cause to a higher transport prices (p. 13)
	Survey, interviews, etc.	- due to low load factor, more trips must be made, this cause to increase in fuel consumption (p. 117) - increase of the number of operational hours per day and thus hire extra labor in periods with high transport prices (p. 117) - decreasing of reliability of the quantity delivered to the customer (p. 129) - decreasing in reliability of arrival time of inland ships due to longer waiting times in front of locks (p. 129) - high water levels cause to problems for containers in area with low height of bridges (p. 129/130)
17. Opportunities	***Literature review***	- increase in CO2 emissions may cause to more use of inland waterway transport because it is a more environmental friendly mode than road transport (p. 42)
	Survey, interviews, etc.	-

18. Adaptation measures	***Literature review***	-
	Survey, interviews, etc.	- inland waterway carriers may have to search for alternative routes to mitigate leading detours and delays (p.13)
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	-
20. Barriers of implementation		-
21. Open research issues		- need for research at the operational or technical level like new logistical concepts and new ship designs (p. 130)
22. Remarks		-

(Own illustration.)

Table 25: Data extraction form of PAPPIS, C. P. (2011)

1. Title		**Climate change, supply chain management and enterprise adaptation: Implications of global warming on the economy**
2. Author		PAPPIS, C. P.
3. Publication year		2011
4. Country of origin		Greece
5. Publication type		Book
6. Source		Hershey, Pa. [u.a.]: Information Science Reference. - xvi, 338 S.; Ill. ISBN: 978-1-61692-802-5 (ebook)
7. ISI-impact factor		-
8. Database		WISO Wirtschaftsdatenbank
9. Search term		"global warming" AND adapt* AND "supply chain management" "global warming" AND adapt* AND "supply chain"
10. Paper type		Empirical
11. Paper method		Content analysis and survey
12. Geographical region		Global
13. Research period		-
14. Transportation mode		Rail transportation Road transportation Airport
15. Weather condition	**Short run**	- storm (p. 121)
	Long run	- flooding (p. 121) - increase in temperature (p. 121) - sea level rise (p. 121)

16. Risks	***Literature review***	- damage of transport infrastructure cause to slow delivery of inputs and supplies via road, sea or rail (p. 94) - high temperatures can cause to increase in buckled rails and rutted roads (p. 94) - very costly and catastrophic implications in all kinds of material movement (p. 111) - delays leading to paying compensation to operators (p. 112) - breaking down of overhead cables because of strong winds (p. 112) - through heavy rainfall drainage issues (p.112) - securing stability of structures (bridges, watering of tunnels) (p. 112) - changing of requirements for improved highway drainage, deterioration of highway infrastructure (earthworks, bridges, pavements etc.) (p. 112) - impact on underground tunnels due to change in moisture content through flooding (p. 112) - dewatering of tunnels (in the case of railways) (p. 121) - demand for air-conditioning lean to higher energy consumption (p. 113)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	-
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	- required management of weather impacts on the railway infrastructure (producing data and scenario analysis) (p. 112) - Airport: thermal expansion of runways (p. 112)
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	-
20. Barriers of implementation		-
21. Open research issues		- required comprehensive list of climate change impacts on transport and corresponding actions to cope with them (p. 111) - developing clear guidance on building standards to reflect the probabilities (p. 112) - developing more joined-up approaches to drainage issues (p. 112)
22. Remarks		- focus of study is the supply chain in every standard company

(Own illustration.)

Table 26: Data extraction form of EISENACK, K. et al. (2012)

1. Title		**Adaptation to climate change in the transport sector: A review of actions and actors**
2. Author		EISENACK, K.; STECKER, R.; RECKIEN, D.; HOFFMANN, E.
3. Publication year		2012
4. Country of origin		Germany
5. Publication type		Journal
6. Source		Mitigation and Adaptation Strategies for Global Change, Vol. 17, No. 5, p. 451-469
7. ISI-impact factor		-
8. Database		EBSCO Host: Business Source Complete, Academic Source Complete, EconLit with Full Text, E-Journals
9. Search term		"climate change" AND adapt* AND transport*
10. Paper type		Empirical
11. Paper method		Content analysis
12. Geographical region		Global
13. Research period		2005 - 2009 (time range of analysed papers) (p. 2)
14. Transportation mode		Road transportation Rail transportation Water transportation Airport
15. Weather condition	**Short run**	-
	Long run	- flooding (p. 452) - permafrost (p. 452)
16. Risks	***Literature review***	- flooding of roads and railways, threats to passenger safety during heat waves, delays due to storms (p. 452) - permafrost melting under roads in the arctic, concrete degradation (p. 452)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	-
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	- education and training of professionals (p. 458) - building seawalls against flooding (p. 458) - retreat from floodplains (p. 458) - providing alternative routes (p. 458) - formation of new institutional and contractual relationships (p. 459) - air conditioning of vehicles (p. 459) - modifying the design of the fill and soil compaction when using excessively dry materials in the construction of roads (p. 459) - use of granular protection against erosion (p. 459) - facilitating understanding of climate change in management (p. 459) - creating databases of public infrastructure (p. 459) - financial and insurance instruments (p. 460) - use of continuous welded rail lines (p. 462)
	Survey, interviews, etc.	-

19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	-
20. Barriers of implementation		-
21. Open research issues		- need of monitoring and information gathering systems, which assessing risks and consequences of climate change before starting new projects (p. 460) - ranking identified risks (p. 460) - developing action plans to manage prioritized risks (p. 460)
21. Open research issues		- research in flexible/adaptable designs (p. 460)
22. Remarks		-

(Own illustration.)

Table 27: Data extraction form of LOVE, G. et al. (2010)

1. Title		**Climate change, climate variability and transportation**
2. Author		LOVE, G.; SOARES, A.; PÜEMPEL, H.
3. Publication year		2010
4. Country of origin		Switzerland
5. Publication type		Journal
6. Source		Procedia Environmental Sciences, Vol. 1, Issue 0, p. 130–145
7. ISI-impact factor		-
8. Database		EBSCO Host: Business Source Complete, Academic Source Complete, EconLit with Full Text, E-Journals
9. Search term		"climate change" AND adapt* AND transport*
10. Paper type		Empirical
11. Paper method		Content analysis
12. Geographical region		Global
13. Research period		-
14. Transportation mode		Water transportation Rail transportation Airport
15. Weather condition	**Short run**	- heavy rain (p. 135) - storm (p. 135)
	Long run	- flooding (p. 135) - snow (p. 135) - temperature extremes (p.135) - sea level rise (p. 135)

16. Risks	***Literature review***	- delays, reduced speeds, stresses on vehicle components and tires (p. 135) - flooding causing road and airport closures, rerouting, weak and uneven braking (p. 135) - drought causing risk of dust and smoke reducing visibility lean to increased forest fires with smoke and flames causing road and highway closures (p. 135) - high temperatures affecting take-offs and landings at airports because of less lift (p. 135) - supply chain disruptions (p.135) - damage to infrastructure and blocked railroads (p. 135) - rail buckling (sun kinks), reduced speeds on rails (p. 135)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	- possible reductions in the costs of snow and ice control, safer travel conditions through higher temperature (p.135)
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	- substantial investment in improved ventilation and air conditioning on-board trains (p. 137) - flood walls like in London - protecting against storm events (p. 141)
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	-
20. Barriers of implementation		-
21. Open research issues		- need of higher efficiency engine systems (less heat loss, more energy converted to kinetic energy of the train) with regenerative breaking rather than friction-based breaking (p. 137)
22. Remarks		-

(Own illustration.)

Table 28: Data extraction form of SCHWARTZ, H. G., Jr. (2011)

1. Title	**Another challenge for the transportation community**
2. Author	SCHWARTZ, H. G., JR.
3. Publication year	2011
4. Country of origin	USA
5. Publication type	Report
6. Source	Transportation Research Circular, Issue: E-C152
7. ISI-impact factor	-
8. Database	Google Scholar
9. Search term	AND adapt * AND transport* "climate change" -mitigation -production
10. Paper type	Empirical
11. Paper method	Content analysis
12. Geographical region	Global (USA)
13. Research period	-
14. Transportation mode	Road transportation Rail transportation

15. Weather condition	**Short run**	- storm (p. 4)
	Long run	- temperature extremes (p. 4) - sea level rise (p. 4)
15. Weather condition	**Long run**	- changes in precipitation (p. 4) - flooding (p. 4)
16. Risks	***Literature review***	- overload of culverts, storm water drainage systems, and natural drainage basins through heavy rainfall (p. 3) - infrastructure built on permafrost will be endangered cause to creating of another challenge to accessing parts of Alaska by rail or road (p. 3) - direct and indirect consequences through climate change impacts including cost to society and the economy (p. 4)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	- longer shipping season for inland waterways through higher temperatures (p. 2)
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	- monitoring and modifying solutions of shortcomings (p. 6) - protection of infrastructure with dikes and levees (p. 8) - eluviation of critical infrastructure (p. 8) - abandon or move coastal transportation system (p. 8) - providing of good evacuation routes and operational plans (p. 8) - replacement of bridge and highway expansion joints (p. 8) - longer runways to account for lower lift-off capacities at airports (p. 8) - updating of Federal Emergency Management Agency flood plain maps (p. 8) - update hydrological storm frequency curves (p. 8) - protection of existing and vulnerable structures, e.g., bridge piers (p. 8) - better land use planning in flood plains (p. 8) - construction of storm retention basins for short, high intensity storms, i.e., flash flooding (p. 8) - build or reconstruct more robust and resilient structures (p. 8) - installation of surge barriers on vulnerable rivers (dikes) (p. 8)
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	-
20. Barriers of implementation		-
21. Open research issues		- research on new, heat-resistant or resilient materials (p. 8) - developing of new design standards for hydraulic structures, e.g. culverts and drainage channels (p. 8)
22. Remarks		-

(Own illustration.)

Table 29: Data extraction form of STEWART, B. et al. (2011)

1. Title		**Climate change adaptation and preparedness planning for airports**
2. Author		STEWART, B.; KLEIN, T.; VIGILANTE, M.
3. Publication year		2011
4. Country of origin		USA
5. Publication type		Report
6. Source		Transportation Research Circular E-C152
7. ISI-impact factor		-
8. Database		Google Scholar
9. Search term		AND adapt * AND transport* "climate change" -mitigation -production
10. Paper type		Empirical
11. Paper method		Content analysis
12. Geographical region		Global (USA)
13. Research period		-
14. Transportation mode		Airport
15. Weather condition	**Sort-run**	- storm surges (p. 38) - storm (p. 38)
	Long run	- changes in precipitation (p. 38) - temperatures extremes (p. 38) - sea level rise (p. 38)
16. Risks	***Literature review***	- dryer soils and more runoff and erosion, more forest and grassland fires lean to smoke which affects aircraft operations (p. 38) - airport closure and delayed aircraft operations due to flooding or storm (p. 41) - increased energy consumption for heating, ventilation, and air conditioning due to extreme heat events (p. 41) - computer system downtime or data loss and cyber security risks due to power failures or building damage related to wind (p. 41) - operations and maintenance disruptions due to all climate extremes (p. 41) - airport employee chaos due to regional and family demands for their services (p. 41) - decreasing in contractor satisfaction due to lack of performance (equipment, supplies or labor unavailability) (p. 41) - economic loss to regional businesses (p. 41)
	Survey, interviews, etc.	-
17. Opport-unities	***Literature review***	-
	Survey, interviews, etc.	-

18. Adaptation measures	***Literature review***	- selection or specification of materials and the design of expansion joints (p. 40) - lengthening runways for degradation of future aircraft take off performance (p. 40) - hardening facilities for higher wind loads (e.g., building shell replacement, aerodynamic load analysis of building complexes, and extra tie-downs for aircraft and containers) (p. 40) - rebuilding, relocating, or abandoning shoreline facilities (e.g., seawalls, sewage treatment outfalls, and building and runway foundations) due to expected higher sea levels (p. 41)
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	- building communications, collaboration, and strategic alignment with the full range of airport stakeholders (p. 42) - community mapping and other ways to assure comprehensive stakeholder involvement in adaptation planning and implementation (p. 43)
	Survey, interviews, etc.	-
20. Barriers of implementation		-
21. Open research issues		- matrix of risks, potential solutions, feasibility, and co-benefits applicable to the airport context (p. 43) - generic work plan for developing a holistic adaptation plan for an airport or airport system (p. 43) - prioritized list of research needs to accelerate airports adaptation toolbox development (p. 43) - methods for regional data-sharing of climate change related data and forecasts (p. 43) - research in new materials for implications for higher average temperatures and higher extremes (p. 43) - need of efficient methods for storing and handling alternative fuels (p. 43) - need of methods for valuing and pricing climate change adaptation actions (p. 43) - developing of ways to incorporate climate change considerations into risk management and asset management systems (p. 43)
22. Remarks		-

(Own illustration.)

Table 30: Data extraction form of GARDINER, L. et al. (2008)

1. Title	**Climate change effects on the land transport network volume One: Literature review and gap analysis**
2. Author	GARDINER, L.; FIRESTONE, D.; OSBORNE,A.; KOUVELIS, B.; CLARK, A.; TAIT, A.
3. Publication year	2008
4. Country of origin	New Zealand
5. Publication type	Report
6. Source	NZ Transport Agency Research Report 378 ISBN: 978-0-478-34663-3 (PDF)
7. ISI-impact factor	-
8. Database	Google Scholar
9. Search term	AND adapt * AND transport* "climate change" -mitigation -production
10. Paper type	Empirical
11. Paper method	Stakeholder survey

12. Geographical region		Global (New Zealand)
13. Research period		2008/2009 (p. 18)
14. Transportation mode		Road transportation Rail transportation Water transportation
15. Weather condition	**Short run**	- heavy rainfall (p. 75) - storm surges (p. 75) - storm (p. 76)
	Long run	- flooding (p. 75) - sea level rise (p. 75) - snow and ice (p. 76) - drought (p. 76) - increase in temperatures (p. 76)
16. Risks	***Literature review***	-
	Survey, interviews, etc.	- slope and batter slips as well as risk of washouts cause disruption to the operation of roads owing to blockages (p. 75) - reduced surface friction and risk of 'loss-of-control' accidents (p. 75) - damage to drainage, culvert and bridge infrastructure from increased waterway flows and debris (p. 75) - moderate risk of reduced structure lifespan caused by corrosion (p. 75) - due to storm → high risk of vehicles being blown off roads in exposed areas (p. 75) - temporary road closure and bridge restrictions (p. 76) - increased snowmelt contributes to flooding issues (p. 76) - roadside fires cause damage to equipment and vegetation and disrupt traffic (p. 76) - pavement surface bleeding (p. 76) - increased dust from unsealed roads (p. 76) - requiring extensive repairs and causing closure of roads for short or extended periods (p. 77)
16. Risks	***Survey, interviews, etc.***	- potential consequences include damage to road assets, road users and road freight (p. 77) - requiring more frequent inspections, repairs and potential road closures during washouts (p. 77) - increased scour of bridge piers, river bank protection works etc. will require extensive repairs (p. 77) - due to storm → blow vehicles off the road in exposed places, with resulting risk of injury or death (p. 79) - damage signs and infrastructure (p. 79) - rail track buckling at higher temperatures can lead to trains derailing, resulting in major damage to freight, equipment and infrastructure, and potential harm to personnel and passengers (p. 88) - speed restrictions will result in increased delays to services and raised frequency of inspections (p. 88)
17. Opportunities	***Literature review***	-
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	-
	Survey, interviews, etc.	-

19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	-
20. Barriers of implementation		-
21. Open research issues		- need for identifying location of areas susceptible to coastal flooding/inundation (p. 81) - need for resistant drainage structures to cope with increased water flows (p. 81) - developing of design standards to cope with identified climate change (p. 81) - nationwide assessment of rail track levels in relation to mean sea level and associated prediction in sea level rise and storm surge (p. 110) - identification of areas and regions vulnerable to these effects and at risk of operational effects or adaptation requirements (p. 110) - rail network-wide assessment of existing drainage culvert and bridge structures - developing of new design and ballast stability changes to cope with rising groundwater levels (p. 111)
22. Remarks		-

(Own illustration.)

Table 31: Data extraction form of TRANSPORTATION RESEARCH BOARD (Ed.) (2008)

1. Title		**Potential impacts of climate change on U.S. transportation**
2. Author		TRANSPORTATION RESEARCH BOARD (Ed.)
3. Publication year		2008
4. Country of origin		USA
5. Publication type		Report
6. Source		Transportation Research Board Special Report 290; ISBN: 978-0-309-11306-9
7. ISI-impact factor		-
8. Database		http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf
9. Search term		Reference harvesting in EISENACK, K. et al. (2012) "Adaptation to climate change in the transport sector: a review of actions and actors"
10. Paper type		Empirical
11. Paper method		Content analysis
12. Geographical region		Global (USA)
13. Research period		-
14. Transportation mode		Road transportation Rail transportation Airport
15. Weather condition	**Short run**	- storm (p. 93) - storm surge (p. 93) - intensive precipitation (p. 89)
	Long run	- flooding (p. 89) - sea level rise (p. 89) - temperature extremes (p. 85)

16. Risks	***Literature review***	- affecting of moisture levels through high precipitation can cause to instability of pavement (p. 84) - affecting of stream flow and sediment delivery in some locations effects on bridge foundations (p. 84) - deformation of rail lines and derailments cause to speed restrictions through heat (p. 86) - heat expands bridge joints, which affects bridge operation and increasing maintenance costs (p. 86) - thawing of permafrost could undermine runway foundations, necessitating major repairs or relocation of some landing strips (p. 88) - through heat buckling of runways (p. 88) - through updating design specifications to provide for greater capacity and shorter recurrence intervals lead to increasing system costs (p. 89) - low-lying bridge and tunnel entrances vulnerable to flooding and culverts could be undersized for water flows (p. 89) - interruption of road and rail traffic is likely to become more common with more frequent flooding (p. 89) - more freeze–thaw conditions may occur, thus creating frost heaves and pot-holes on road and bridge surfaces and resulting in load restrictions on certain roads to minimise the damage (p. 86) - excessive heat cause to increasing in wildfires, which lead to road and rail closures in affected areas, and softening asphalt and
16. Risks	***Literature review***	increasing rutting (p. 86) - increases in temperature will affect airport ground facilities (e.g. runways) (p. 88) - extreme heat lead to payload restrictions, flight cancellations and service disruptions (p. 88) - intense precipitation cause to in increasing disruptions and delays in air service and periodic airport closure (p. 92)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	- warm winter temperatures shortened the season for ice roads that provide vital access to communities and industrial activities in remote areas (p. 85) - warm winter temperatures will bring reductions in snow and ice removal costs, lessen adverse environmental impacts from the use of salt and chemicals on roads and bridges (p. 86) - extend the construction season, and improve the mobility and safety of passenger and freight travel through reduced winter hazards (p. 86)
	Survey, interviews, etc.	-
18. Adaptation Measures	***Literature review***	- airports can be protected from flooding by dikes (p. 92) - developing new coalitions and organisational arrangements which address the impacts of climate change (p. 142) - incorporating responses to more extreme weather events into routine operations (p. 171) - improving collaboration with emergency managers recognizing weather and emergency management (p. 171) - sharing best practices (p. 171) - more stringent land use controls and flood insurance requirements (p. 171)
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	- collaboration with climate scientists and meteorologists a priority (p. 141)
	Survey, interviews, etc.	-

20. Barriers of implementation	- significant costs of designing infrastructure (p. 131) - resource constraints (p. 131) - lack of relevant information and guidance on which to base appropriate actions (p. 131)
21. Open research issues	- need for more strategic, risk-based approaches to decision making and infrastructure design (p. 141) - need for design changes to harden long lived infrastructure in locations (p. 171) - development of new standards to address climate change (p. 171) - need of new partnerships and organisational arrangements for better alignment with climate impacts (p. 172)
21. Open research issues	- developing climate data and decision support tools that incorporate the needs of transportation decision makers (p. 208) - developing and implementing monitoring technologies for major transportation facilities to provide advance warning of pending failures (p. 208) - developing a mechanism for sharing best practices to address potential impacts of climate change (p. 208)
22. Remarks	-

(Own illustration.)

Table 32: Data extraction form of KOETSE, M. J.; RIETVELD, P. (2009)

1. Title		**The impact of climate change and weather on transport: An overview of empirical findings**
2. Author		KOETSE, M. J.; RIETVELD, P.
3. Publication year		2009
4. Country of origin		Netherlands
5. Publication type		Journal
6. Source		Transportation Research Part D, Vol. 14, Issue 3, p. 205–221
7. ISI-impact factor		-
8. Database		Google Scholar
9. Search term		Reference harvesting in EISENACK, K. et al. (2012) "Adaptation to climate change in the transport sector: a review of actions and actors"
10. Paper type		Empirical
11. Paper method		Content analysis
12. Geographical region		Global
13. Research period		-
14. Transportation mode		Road transportation Rail transportation Water transportation Airport
15. Weather condition	**Short run**	- storms (p. 207) - storm surges (p. 207)
	Long run	- increases in temperature (p. 207) - heat waves (p. 207) - drought (p. 207) - sea level rise (p. 207) - changes in precipitation pattern (p. 207) - flooding pattern (p. 207)

16. Risks	***Literature review***	- railway companies and airports stop operations due to extreme wind conditions (p. 206) - extreme weather may lead to accidents on roads, implying delays for both passenger and freight transport (p. 206) - small parts of roads and railroads are affected by regular inundation, this may still lead to large impacts due to network effects (p. 208) - network are affected this may lead to large disruptions at the network level (p. 208) - particular flood lead to substantial damages and travel delays on highways and railroads (p. 209) - impact on patterns in production and the associated patterns in trade and freight transport (p. 210) - days with low water levels will increase, thus makes inland shipping less attractive relative to road or rail transport (p. 212) - poor visibility in the summer months and rain storms in the winter months lead to delays and numerous cancellations (p. 112) - increase the number of road accidents (p. 214) - number and intensity of traffic jams, leading to substantial time losses by road users → delays (p. 214) - changes in traffic-flow and- volume reflect changes in demand for transport, changes in route choice and postponement of trips (p. 115) - impact of sea level rise on various types of transportation infrastructure along the East Coast of the United States (p. 208) - potential disruptions and associated welfare loss are clearly substantial (p. 208) - costs associated with infrastructure damages by future sea level rise, storm surge and flooding can be substantial (p. 209) - costs due to delays, detours and trip cancellation, may also be substantial (p. 209) - higher temperatures lead to higher demand for electricity/energy for cooling (p. 211) - inland waterway vessels to use only part of their maximum capacity, which may considerably increase transportation costs (p. 211) - lack of visibility leads to capacity restrictions through restriction of the Ministry of Transport (p. 112) - the river Rhine it is expected that in summer, more and longer periods with low water levels will occur, this lead to increase transport prices per ton → reduction in load factor (p. 217)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	- demand for energy during the winter months will decline (p. 211) - decrease the probability of snowfall lead to decreasing congestion and improving traffic safety (p. 214)
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	- airports should have a sufficient runway capacity under various wind directions (p. 212)
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	-
20. Barriers of implementation		-

21. Open research issues	- need of ex-ante information on vulnerable networks (flooding) and accessibility of crucial facilities for decision making on potential adaptation strategies (p. 209)
22. Remarks	-

(Own illustration.)

Table 33: Data extraction form of ARNBJERG-NIELSEN, K.; FLEISCHER, H. S. (2009)

1. Title		**Feasible adaptation strategies for increased risk of flooding in cities due to climate change**
2. Author		ARNBJERG-NIELSEN, K.; FLEISCHER, H. S.
3. Publication year		2009
4. Country of origin		Denmark
5. Publication type		Journal
6. Source		Water Science & Technology, Vol. 60, Issue 2, p. 273-281
7. ISI-Impact factor		1.056
8. Database		Google Scholar
9. Search term		Reference harvesting in EISENACK, K. et al. (2012) "Adaptation to climate change in the transport sector: a review of actions and actors"
10. Paper type		Empirical
11. Paper method		Case Study
12. Geographical region		Global
13. Research period		-
14. Transportation mode		Road transportation Rail transportation
15. Weather condition	**Short run**	- extreme rainfall (p. 273)
	Long run	- rising sea level (p. 273)
16. Risks	***Literature review***	-
	Survey, interviews, etc.	- extra costs of operation and maintenance if pipe diameters will increase (p. 276) - traffic delays (p. 277) - roads destruction (p. 277) - electricity outfall (p. 277) - sewer damage (p. 277) - administration costs (p. 277) - all risks lead to high costs (p. 276)
17. Opportunities	***Literature review***	-
	Survey, interviews, etc.	-
18. Adaptation measures	***Literature review***	-
	Survey, interviews, etc.	- larger pipes, structures, pumps (p. 278) - installing outlet facilities from the storm sewer system to the green area (p. 278) - warning systems to the public (p. 278) - construction of dikes to protect the cities from storm surges (p. 279) - increase the capacity of the urban drainage infrastructure (p. 280)

19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	- maintaining the frequency of exceeding the pipe capacity (and thus increase the capacity of the sewer system) (p. 275) - maintaining the present capacity of the sewer system (and thus increase the frequency of surcharge) (p. 276)
20. Barriers of implementation		-
21. Open research issues		-
22. Remarks		-

(Own illustration.)

Table 34: Data extraction form of KIRSHEN, P. et al. (2008)

1. Title		**Climate change and coastal flooding in Metro Boston: Impacts and adaptation strategies**
2. Author		KIRSHEN, P.; KNEE, K.; RUTH, M.
3. Publication year		2008
4. Country of origin		USA
5. Publication type		Journal
6. Source		Climatic Change, Vol. 90, Issue 4, p. 453–473
7. ISI-Impact factor		3.106
8. Database		Google Scholar
9. Search term		Reference harvesting in EISENACK, K. et al. (2012) "Adaptation to climate change in the transport sector: a review of actions and actors"
10. Paper type		Empirical
11. Paper method		Content analysis & Scenario analysis
12. Geographical region		Local (Boston)
13. Research period		-
14. Transportation mode		Rail transportation
15. Weather condition	**Short run**	- storm surges (p. 457)
	Long run	- flooding (p. 456) - sea level rise (p. 457)
16. Risks	***Literature review***	- concluded that both low-lying infrastructure and wetlands would be at-risk (p. 459)
	Survey, interviews, etc.	- residential, commercial, and industrial areas flooded and economic damages (p. 461) - increased cost of floodproofing new structures is insignificant compared to the total cost of new construction (p. 461) - drainage of any areas behind seawalls flooded during storms (p. 462) - high adaptation costs through coastal flooding in metro Boston (p. 470)
17. Opportunities	***Literature review***	-
	Survey, interviews, etc.	-
18. Adaptation	***Literature review***	- seawalls (dikes) for coastal flooding protection (p. 462)

measures	***Survey, interviews, etc.***	-
19. Adaptation strategy	***Literature review***	-
	Survey, interviews, etc.	- use of expensive structural protection in areas that are highly developed and take a less structural approach in less developed areas and/or environmentally sensitive areas (p. 471)
20. Barriers of implementation		-
21. Open research issues		-
22. Remarks		-

(Own illustration.)

Table 35: Data extraction form of TAYLOR, M. A. P.; PHILP, M. (2010)

1. Title		**Adapting to climate change – implications for transport infrastructure, transport systems and travel behaviour**
2. Author		TAYLOR M. A. P.; PHILP M.
3. Publication year		2010
4. Country of origin		Australia
5. Publication type		Journal
6. Source		Road and Transport Research; Vol. 19, Issue 4, pp. 66-79
7. ISI-Impact factor		-
8. Database		Web of Science
9. Search term		“extreme weather” AND adapt* AND transport*
10. Paper type		Empirical
11. Paper method		Content analysis
12. Geographical region		Global (Australia)
13. Research period		-
14. Transportation mode		Road transportation Rail transportation
15. Weather condition	**Short run**	- storm and strong wind (p. 69) - rain (p. 71) - storm surge (p. 69)
	Long run	- temperature extremes (p. 69) - solar radiation (p. 69) - high temperature (p. 69) - flooding (p. 69) - sea level rise (p. 69) - decrease in precipitation (p. 69)

16. Risks	***Literature review***	- increase the expansion stress and movement experienced on steel bridges and rail tracks due to extreme temperatures (p. 69) - expansion of concrete joints, protective cladding, coatings and sealants on bridges due to extreme temperatures (p. 69) - reduction of life of asphalt road surfaces through an increase in the embrittlement of the surface chip seals due to higher temperatures combined with increased solar radiation (p. 69) - softening of asphalt and may lead to traffic related rutting due to high temperatures (p. 69) - buckling of pavements due to high temperatures (p. 69) - increased ground movement, changes in the watertable and associated increases in the salinity of soils due to decreased in precipitation (p. 69) - degradation of materials, structures, reinforcement and foundations, reduce the life expectancy of the transport infrastructure due to decrease in precipitation (p. 69) - increase of maintenance costs (p. 69) - significant damage to road, rail, bridge and tunnel infrastructure due to flooding (p. 69) - impacts of precipitation changes to pavement and drainage design, foundation conditions due to flooding (p. 69) - damage of tunnels and culverts (due to increased tidal and salt gradients, ground water pressure and corrosion of materials) due to sea level rise and the increased potential for storm surge (p. 69) - damage of bridges due to strong winds (p. 69) - rain and wet road conditions as significant contributors to road fatalities and crashes (p. 71) - substantially increased risk of an accident, particularly in single vehicle accidents, under heat stress conditions (p. 71) - increased risk for bushfires may also alter driver behavior due to a reduction of visibility due to smoke (p. 71) - increasing of costs due to delays, losses from toll roads, freight supply interruption, detours and trip cancellations (p. 70) - insurers may act to reduce their potential exposure through limitations in event coverage due to increasing of the understanding and occurrence of climate change impacts (p. 70) - increased extreme precipitation events therefore may periodically increase pressure on alternative transport modes (p. 71) - climate change will affect the function of traffic systems by
16. Risks	***Literature review***	reducing traffic speed and volume, increasing travel time delay, and decreasing roadway capacity → cause delays (p. 71) - increased temperatures are predicted to result in more vehicle overheating and breakdowns, and lead to faster tyre deterioration resulting in blow outs → traffic disruptions (p. 71) - increasing fuel use, which is amplified further by the increased use of air conditioning in vehicles → increasing costs (p. 71)
	Survey, interviews, etc.	-
17. Opportunities	***Literature review***	-
	Survey, interviews, etc.	-

18. Adaptation measures	***Literature review***	- approach to predicting, planning and designing for storm surges (p. 69) - setting more rigorous design standards for flooding and construction of infrastructure in saturated soils, and changes in materials specifications to cope with the corrosive nature of the coastal environment (p. 69) - changes in culvert design and the design and materials specifications of road subgrade due to heavy precipitation (p. 69) - driver education and increased deployment of advisory systems → provision of adaptation mechanism for user behaviour in the changing climate conditions (p. 71) - robust transport network → alternative travel paths to ensure the effective functioning of systems (p. 71) - removing any limitations imposed in road work areas to minimise delays (p. 72) - education of transportation community about the importance of addressing climate change → top level leadership is needed to provide clarity in policy direction (p. 74) - climate change focused partnerships should be developed across all governance levels and include private industry (p. 74) - decision support systems (p. 74)
	Survey, interviews, etc.	-
19. Adaptation strategy	***Literature review***	- climate change adaptation measures must include planning to reduce vulnerability → development, analysis and revision of planning systems and practices (p. 70) - accommodate emergency services and planning particularly with respect to emergency evacuations (p. 71) - deployment of intelligent transportation systems in urban areas, and supplementary advisory services to assist rural areas in order to inform drivers of the most efficient evacuation routes as conditions change (p. 72) - synergies should be identified among goals and projects being undertaken across all governance levels and private industry (p. 74)
19. Adaptation strategy	***Survey, interviews, etc.***	-
20. Barriers of implementation		- general lack of knowledge on the need to adapt infrastructure and which adaptation methods should be applied (p. 73) - governance and communication barriers that prevented cooperation between stakeholders (p. 73) - limited funding for planning and implementing adaptation measures (p. 73)
21. Open research Issues		- required approach to develop and implement effective adaptation strategies for Australian transportation infrastructure (p. 76) - more responsibility through Local Governments because it will be a key actors in adapting to the local impacts of climate change and engaging in ground level works (p. 73)
22. Remarks		- the Council of Australia Governments (COAG) is in charge of developing an appropriate governance pathway for facilitating climate change adaptation (p. 74)

(Own illustration.)

Appendix D: Interview guideline

TECHNISCHE UNIVERSITÄT DRESDEN

REG KLAM Regionales Klimaanpassungsprogramm Modellregion Dresden

Fakultät Wirtschaftswissenschaften, Lehrstuhl für Betriebswirtschaftslehre, insb.

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Leitfaden für ein Experteninterview im Rahmen

REG KLAM Regionales Klimaanpassungsprogramm Modellregion Dresden

1. Einführung

- Auftraggeber, Partner (anhand Flyer)
- Ziel des Projektes und des Experteninterviews erläutern:

1) konkrete Fragen an alle Unternehmen
2) falls Interesse an Kooperation im Rahmen des Projektes besteht, Möglichkeiten aufzeigen: Impulse an Forschung, Impulse an Politik, Sparringspartner für Ergebnisse, Referent aus Unternehmen bei Veranstaltungen

- Abgrenzung der beiden Anpassungsformen inside-out und outside-in
- Klimawandel als Teil von verschiedenen Wandelerfordernissen (demographischer Wandel etc.)

2. **Auswirkungen des Klimawandels (Sachsen, Region Dresden, konkreter Standort des Unternehmens)**

- Einstellung zu Klimawandel (allgemein, auf Deutschland, Sachsen, Dresden, Unternehmen) → Sensemaking?
- Kritisches Ereignis/ Durchschnittliche Situation → Critical Incident Technique

Falls Unternehmen sehr uninformiert: Auswirkungen des Klimawandels für Sachsen, die Region Dresden und nach Möglichkeit für das konkrete Gebiet des Unternehmens darlegen (aus Klimadatenbank),

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3. Betroffenheit der Wertschöpfungsstufen vom Klimawandel

- Wertschöpfungsstufen vorstellen
  - Beschaffung,
  - Produktion,
  - Absatz und
  - Entsorgung
  - F&E,
  - Logistik,
  - Personal/ Organisation,
  - Marketing,
  - Controlling

- Direkte Auswirkungen des Klimawandels auf ökonomische Leistung/ auf alle einzelnen Wertschöpfungsstufen erörtern
  → Temperatur (Temperaturzunahme/ verstärkte Hitzetage),
  → Niederschlag (Niederschlagsabnahme über das gesamte Jahr/ Starkregen/ Dürren),
  → Windgeschwindigkeit (Starkstürme),
  → Strahlung (zunehmende Strahlung),
  → weitere wie Nebel)
  → CIT, falls Erfahrungen vorhanden (hier ist von unserer Seite zu dokumentieren, ob CIT oder hypothetische Antwort)

  a) Wenn Klimaelement X sich erhöht, wie wirkt sich das auf die Wertschöpfungsstufe Y aus? / Wenn ein Extremwetterereignis eintritt, wie wirkt sich das auf die Wertschöpfungsstufe Y aus?
  b) In welchen konkreten Bilanzpositionen könnte sich das widerspiegeln oder: welche ökonomische Steuerungsgröße nutzen Sie in Ihrem Unternehmen für Entscheidungen?

→ *Bilanz/ GuV vorlegen (Anlage 2 & Anlage 3)*

c) Wird der Einfluss des Klimaelements auf die Bilanzposition negativ oder positiv sein und mit welcher Wahrscheinlichkeit wird die Änderung eintreten – was schätzen Sie?

d) Welche Maßnahmen zur Anpassung an den Klimawandel wurden bisher umgesetzt?

e) Sind weitere Maßnahmen zur Anpassung an den Klimawandel geplant?

f) In welchem Zeitraum sollen diese Maßnahmen umgesetzt werden?

g) Wo könnten Probleme bei der Umsetzung liegen?

h) Schätzen Sie bitte, besteht für die Wertschöpfungsstufe X eher eine Chance oder eher ein Risiko und mit welcher Wahrscheinlichkeit wird die Chance bzw. das Risiko eintreten?

→ *Risikomatrix vorlegen und durch den Interviewten die einzelnen Wertschöpfungsstufen eintragen lassen (Anlage 4)*

i) Welche in Ihrer Branche möglichen/erforderlichen Anpassungsmaßnahmen auf der Wertschöpfungsstufe X sind Ihnen bekannt?

j) Welche in Ihrer Branche möglichen/erforderlichen Anpassungsmaßnahmen auf der Wertschöpfungsstufe X könnten Sie sich vorstellen?

k) Welche Kosten würden aufgrund dieser Maßnahme entstehen und auf welche Bilanzposition würden sich diese Ausgaben auswirken?

→ *Bilanz/ GuV vorlegen (Anlage 2 & Anlage 3)*

l) Welche Voraussetzungen sind notwendig, damit sich Unternehmen anpassen können? (interne Ressourcen, externe Faktoren)

4. Rahmenbedingungen für das Unternehmen *(Anlage 5: Makro- und Aufgabenumfeld des Unternehmens)*

   a) Wie könnten sich die politischen/ ökonomischen/ gesellschaftlichen/ technologischen/ ökologischen Rahmenbedingungen im Zusammenhang mit der Klimaanpassung an den Klimawandel ändern?
   b) Wie würden sich diese politischen/ ökonomischen/ gesellschaftlichen/ technologischen/ ökologischen Veränderungen auf Ihr Unternehmen auswirken?

5. Stakeholder/ Anteilseigner des Unternehmens

   a) Welche Anforderungen könnten Staat/ Ihre Eigentümer/ Ihre Kreditgeber/ Ihre Versicherer/ Ihre Lieferanten/ Ihre Kunden/ Ihre Mitarbeiter/ Öffentlichkeit aufgrund des Klimawandels stellen?
   b) Wie könnte Ihr Unternehmen auf die Veränderungen reagieren?

6. Möchten Sie weitere Aspekte hinzuzufügen, die für die Anpassung Ihres Unternehmens an den Klimawandel oder andere Herausforderungen relevant sind?

7. Unternehmensangaben

-Position des Befragten:

-Qualifikation des Befragten:

-Firma:

-Konkreter Standort:

-Branche:

-Produkt/ Dienstleistung:

-Größe:
(MA/Umsatz (Kriterien der KMU-Gesetzgebung - Empfehlung 2003/361/EG 6.Mai09)

-Wertschöpfungstiefe:

-Planungshorizont: …….. Jahre

-Bewusstsein des Klimawandels Ihres Unternehmens:
Nein – gering – eher gering – eher hoch – hoch

-Schlüssel – Klimasignal:

-Schlüssel – Klimasensitivitätserwartung

-Schlüssel – Anpassungsmaßnahme:

Anlage 1: Wertschöpfungskreis

Anlage 2: Bilanz

Anlage 3: Gesamtkosten-/ Umsatzkostenverfahren

Anlage 4: Risikomatrix

Anlage 5: Makro- und Aufgabenumfeld des Unternehmens

Appendix E: Code system applied to interviews

Company A: Tour operation
Company B: Road and rail transportation
Company C: Road transportation
Company D: Road transportation
Company E: Air traffic

Table 36: Statements on climate change impacts on a company's operation

Climate change impacts on a company's operation				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	U: Also den Klimawandel nehmen wir täglich wahr.	9	9	Yes
B	U: Jedes Jahr. 2002 am stärksten durch das Hochwasser, […]	9	9	Yes
E	I: Meine allererste Frage wäre: Haben Sie als Unternehmer den Klimawandel schon einmal wahrgenommen? U1: Das hatte ich eben schon skizziert, dass wir als Flughafen natürlich in einer Branche tätig sind, die Wettereinflüssen, ich will nicht sagen extrem, aber schon in großem Maße ausgesetzt ist.	17	18	Yes
C	U: Kann ich nicht beurteilen, weiß ich jetzt nicht, worauf das hinausgeht, weil wie -? Keine Ahnung.	20	20	No
D	I: Also, waren Sie selbst noch nicht vom Klimawandel betroffen? U: Nein.	20	21	No

(Own illustration.)

Table 37: Interview statements on heavy snow

Weather condition – Heavy snow				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	U: […] Also, dass wir die größten Flugausfälle immer im Januar haben. Also, das ist zum Beispiel so eine Geschichte. I: Das hat jetzt was mit dem Schnee zu tun? U: Mit Schnee.	67	69	Lost trips in logistics of a company → negative impact
C	I: Ok, gut. Sonstiges noch? Was vielleicht Schnee-Ereignisse anbetrifft? Hat das noch einen Einfluss? U: oder Regen ist egal. Wenn es schneit, haben wir viel zu tun.	109	110	More trips → positive impact
D	U: Ja, schon. Wenn es hohe Niederschläge in Form von Schnee im Winter gab und ich habe Ersatzteile bestellt, dann sind die Ersatzteile später gekommen und ich hatte dadurch Ausfälle gehabt, meinen Betriebsfluss zu halten -.	27	27	Maintenance problems in operations → negative impact
D	U: Oder wenn extreme Schneefälle sind, dann lässt der Bürger sein Privat-PKW stehen und ruft sich ein Taxi, weil er sagt: "Ich bin nicht der geübte Fahrer, das sollen dann bitte schön die Profis machen."	44	44	Shift from private car to taxi → positive impact
D	U: Wenn er in unseren Breitengraden extremer wird oder länger andauert wie letzten Winter, wo es dann über mehrere Wochen ging, dann könnte ich mir schon vorstellen, dass es dann -. Wie in 1977/1978 der große Schneefall an der Ostsee. Wenn solche Extreme öfter auftreten würden, dann hätten wir dann schon zu tun.	78	78	More trips → positive impact
E	U: […] Ich muss ganz klar sagen, bei uns liegt der Fokus auf Winter. Sommer ist eigentlich von den Operations her unproblematisch. Winter eher, weil wir müssen dafür sorgen, dass die Startbahn und Flugbetriebsflächen einsatzfähig sind und da ist das größte Hindernis am Ende des Tages ganz klar Schnee.	18	18	Barriers in operation and therefore to higher maintenance of runways and flight lines. → negative impact
E	U: Das war das Einzige, was negativ, nicht durch Erwärmung, sondern durch Schneefall, auftrat: Dass die Lastwagen, welche Flugzeugflächenenteisungsmittel an Bord hatten, nicht zum Flughafen durchkamen. Ich würde mal sagen, wir sind mit einem blauen Auge davongekommen. Es hat gerade noch hingehauen, aber es war knapp.	23	23	Problems in operations → negative impact
E	U: […] Konkret ist das nur der Schneefall, und wenn Vereisung eintritt, auch möglicherweise bei Regen, wenn die Bahn einfach zu kalt ist.	67	67	Problems in operations → negative impact

(Own illustration.)

Table 38: Interview statements on heavy rain

Weather condition – Heavy rain				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	U: […]wenn jemand nur noch Flusskreuzfahren anbietet und die Donau hat in diesem Jahr entweder Hochwasser oder Niedrigwasser, dann bleibt das Schiff liegen. Bei uns mischt sich das alles, durch unser breites Produktangebot. […]	97	97	High water levels due to heavy rain which case to operation problems of ships → negative impact
B	U: […] Wir persönlich haben mit dem Hochwasser, ich sage mal, doch auch schlimme Erfahrungen gemacht […]	114	114	Over a long period lead heavy rain to flooding → negative impact
C	I: Ok, gut. Sonstiges noch? Was vielleicht Schnee-Ereignisse anbetrifft? Hat das noch einen Einfluss? U: Schnee oder Regen ist egal. Wenn es schneit, haben wir viel zu tun.	109	110	More trips → positive impact
D	I: […] War damals, im Jahr 2002, Ihr Taxibetrieb aufgrund des Hochwassers in der Stadt eingeschränkt? U: Eingeschränkt in dem Sinne, dass wir nicht alle Straßen befahren konnten. […]	87	88	Limited route due to flooding (long period of heavy rain) → negative impact
E	U: Also, auch Wasser ist nicht problematisch, oder nur geringfügig problematisch. Da sind bei uns die Sicherheitspuffer, würde ich einfach mal sagen, so groß, dass das kein Problem ist.	18	18	Water occurs through rain which leads to no problems

(Own illustration.)

Table 39: Interview statements on heat waves

Weather condition – Heat waves				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	U: […] Und wenn die dann im Bus in der Hitze sitzen, in der Kälte der Klimaanlage sitzen, ist das unheimlich belastend. […]	41	41	Decreasing of customer satisfaction → negative impact
A	U: […] Dann könnten natürlich im Umfeld Umsätze ausfallen oder wenn jemand nur noch Flusskreuzfahren anbietet und die Donau hat in diesem Jahr entweder Hochwasser oder Niedrigwasser, dann bleibt das Schiff liegen. […]	97	97	Low water levels due to a long period of extreme high temperatures lead to lose in operations → negative impact
B	I: […] in Form von Hitzewellen oder sehr heißen Tagen, in der Vergangenheit einen Einfluss auf Ihre Beschaffung gehabt? Oder können Sie sich vorstellen, dass solche Hitzetage einen Einfluss auf Ihre Beschaffung in der Zukunft haben können? U: Ja, das hatte ich schon gesagt, das sind in aller erster Linie jetzt die Belüftung in den Fahrzeugen, die sich geändert hat.	18	19	Lead to change in transportation technology and adaptation of transport facilities → negative impact
C	U: Naja, sagen wir mal so, sehr hohe Temperaturen in der Woche führen schon hin und wieder mal dazu, dass man das Gefühl hat, dass es eine allgemeine Trägheit in der Bestellung oder so gibt, dass eben nicht so viel davon Gebrauch gemacht wird, von unserer Dienstleistung.	36	36	Loses of trips → negative impacts
D	U: Sowohl als auch. Hitze entsprechend Klimaanlagen, die stärker in Fahrzeugen beansprucht werden, da dass der Kunde verlangt -. Dass man eher mal einen Ausfall hat, den man dann wieder reparieren muss.	33	33	Loses of technological operation → negative impact
D	I: Es gibt ja schon mehrerer Tage im Hochsommer, wo es um die 35°C ist. Nehmen wir einmal an, dass steigert sich auf 40°C und dann auch zwei Wochen lang -. U: Mit der Luftfeuchte dann haben wir hier schon zu kämpfen. Auch mit der Gesundheit der Fahrer, denke ich. Weil diese müssen sich dann dementsprechend vor UV-Strahlung schützen. Da wird bestimmt wieder ein größerer Teil krank sein. […]	40	41	Influence of drivers through air moisture which can lead to sickness → negative impact
D	U: Also, wenn es extrem warm ist, fahren wir mehr Leute, weil sie merken, dass es einen klimatisierten Raum gibt, in dem man sich fortbewegen kann […]	44	44	More trips → positive impact

(Own illustration.)

Table 40: Interview statements on cold waves

Weather condition – Cold waves				
Comp.	*Statement*	*Begin*	*End*	*Comment*
C	U: Weil wir, so wie die Kunden weggehen möchten, so werden wir gefordert. Also, in erster Linie bei Ihnen. Was das normale Tagesgeschäft betrifft, also in der Woche ist es alles nicht so dramatisch. Aber das meiste machen wir fast am Wochenende oder auch abends. Sodass man sagen kann, wenn es lange kalt ist, dann wollen die Leute einfach nicht mehr wirklich gern weggehen. Ich weiß ja nicht, wie es Ihnen da geht, aber mir geht es auch so, ich habe dann auch keine Lust mehr.	42	42	Lost trips → negative impact
D	U: […] Bei Kältewellen sind es dementsprechend die Startbatterien, die dann eher mal den Geist aufgeben. […]	33	33	Damage of starter batteries → negative impact
D	U: […] wenn es extrem kalt ist, dann will der Kunde nicht bei -25°C an der Haltestelle stehen, weil ihm dann die Füße wegfrieren. […]	44	44	Customer dissatisfaction → negative impact

(Own illustration.)

Table 41: Interview statements on storm and strong wind

Weather condition – Storm and strong wind				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	I: Dann würde ich auf den Wind mal gedanklich eingehen. […] U: Gut. Nur wenn es unsere Kreuzfahrten betrifft und das sind natürlich Ereignisse, die also Schiffe in Gefahr bringen usw. […]	82	83	Damage in operations and services → negative impact
C	U: Ja, oder wenn es stürmt. Da irgendwo zu einer Party gehen. So spontane Sachen gleich gar nicht und das ist bei uns und das wechselt bei uns eben auch.	44	44	Loses in trips → negative impact
D	I: […] Jetzt kommen wir zum Klimaelement Wind und Sturm und gehen genau die gleiche Runde wieder durch. Haben Wind und Sturm in der Vergangenheit auf Ihre Beschaffung einen Einfluss gehabt? U: Auf die Beschaffung nicht. Aber auf den allgemeinen Fahrbetrieb. Baum umgestürzt. Durch Stürme waren Straßen gesperrt und wir mussten Umwege fahren. Das hat schon einen Einfluss. […]	125	126	Influence of infrastructure which lead to detours → negative impact

(Own illustration.)

Table 42: Interview statements on radiation

Weather condition – Radiation				
Comp.	*Statement*	*Begin*	*End*	*Comment*
B	U: […] Wenn sie heute hinter ganz normalem Fensterglas sitzen, dann brennt ihnen das auf der Haut und wenn sie jetzt hinter einer getönten Scheibe sitzen, dann ist gerade die ultraviolette Strahlung, gerade durch das, wird sie zurückgehalten. Es ist also auch schon ein anderes Aufheizen im Fahrzeug mit drin. […]	37	37	Impacts to customers and extreme heat in a vehicle → negative impact
D	U: […] Sonne bzw. UV-Strahlung auf die Fahrzeuglacke. […]	138	138	Damage of transportation facility → negative impact

(Own illustration.)

Table 43: Interview statements on physical risks

Risks – Physical				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	U: […] Trotzdem gibt es noch Busse, zum Beispiel, deren Klimaanlagen unter Extremverhältnissen im Sommer ausfallen. […]	41	41	Breakdown of air-conditioning systems through extreme heat.
A	U: […] Also, man merkt immer an den Tagen nach Silvester, also im Januar, dass wenige Abflüge an dem Flughafen sind, insgesamt der Flugverkehr erlahmt. Also, auch die Sensibilität aller Kräfte ein bisschen darunter leidet. Also, dass wir die größten Flugausfälle immer im Januar haben. […] I: Das hat jetzt was mit dem Schnee zu tun? U: Mit Schnee.	67	69	Heavy snow leads to flight cancellations which have an impact on other business services.
B	I: […] Hatten Sie da schon Konsequenzen gespürt? Also ist die Elektronik schon ausgefallen? U: Ja. Das ist natürlich in Größenordnung, vor allen Dingen dort, wo -. Elektronik ist ja auch Wärmeproduzent.	26	27	Disruption of electronic equipment through extreme heat.
B	U: […] Dass man also auch aufpasst, dass man nicht von Erscheinungen, die also hohe Temperaturen z. B. mit sich bringen, wo man schwitzt, sich unwohl fühlt, dass die auch dann letztendlich negativ auf den Fahrer mit einwirken. […]	42	42	High temperatures have an impact on driver's concentration.
B	U: […] meinen an und für sich das Wetter, was örtlich ist. Und wenn ich jetzt den letzten Winter hernehme, da hatten wir gar nicht unweit von uns eine Erscheinung, eine Wettererscheinung, da gab es Eisregen. Das ist in Ort A auch nicht unbekannt, aber in Ort B haben wir einen Eisregen gehabt, der war so schlimm. Dass es eben Leute gibt, die haben dann gesagt: "In Ort A sind wir gefahren." Ich sage Ihnen aber jetzt ganz ehrlich, so ein Eisregen wie die in Ort B hatte, hatten wir nicht. Sonst wären wir auch nicht mehr gefahren. […]	54	54	Customer dissatisfaction because of locally disruption in operation due to weather impacts.

Risks – Physical				
B	U: […]Und wenn heute die Bahn am Bügel eine Vereisung hat, dann fährt die auch nicht mehr. […]	54	54	Lost trips through icing on trams because of non-use.
B	U: Ist immer wichtig. Es war aber schon früher ein Punkt gewesen, es soll nicht ausbleichen so ein Lack. […] Wir wollen also mit den Lacken doch letztendlich erreichen, dass wir hohe Nutzungszeiten bekommen. Dass wir also die Kosten senken. […]	100	100	Bleaching of lack due to radiation lead to higher maintenance costs.
B	U: […] Wir persönlich haben mit dem Hochwasser, ich sage mal, doch auch schlimme Erfahrungen gemacht und wenn man es sich einmal überlegt, dass alle fünf Zufahrten der Straßenbahnen von Ortsteil A aus bis in die Stadt unterbrochen waren -. Da war überhaupt gar keine Trasse mehr befahrbar. […]	114	114	Blocked routs due to flooding and therefore leading to disruption in operations.
C	I: […]Personal und Organisation. Also, wurde in der Vergangenheit Ihr Personal durch zu hohe/ niedrige Temperaturen in irgendeiner Art und Weise schon einmal beeinflusst? U: Sicherlich. Wenn es sehr heiß ist, dann schwitzen sie, die Kollegen, die draußen fahren. Und das ist sicherlich nicht so einfach, was die Konzentration anbelangt. Wenn die Konzentration dann nachlässt, wenn es so sehr warm ist, auch, wenn wir eine Klimaanlage haben.	65	66	High temperatures lead to reduction in concentration of the driver.
C	U: […]Aber Klimaanlage heißt natürlich auch immer irgendwo, dass der Krankenstand höher ist, weil durch diese Pollen und weiß ich, was da für Bakterien durch die Gegend geschleudert werden, durch diese Klimaanlage, dass das wahrscheinlich Auswirkungen hat auf den Gesundheitszustand der Fahrer oder das allgemeine Wohlbefinden. Ich meine, ich merke das ja bei mir selber auch, wenn man lange mit Klimaanlage fährt, da hat man auf einmal irgendwo Kopfschmerzen oder was weiß ich-. Und das geht einigen Kollegen so.	66	66	Failures through illness of drivers due to air-conditioning on hot days.
D	U: In der Form, dass das Fahrzeug nicht fahren konnte, weil das entsprechende Ersatzteil nicht da war, um es Instand zu setzen und weiterfahren zu lassen. In Form von sicherheitsrelevanten Teilen, auf die man bei der Personenbeförderung besonders beachten muss.	29	29	Disrupted supply of important car spare parts lead to non-use of cars and therefore to disrupted operations.
D	U: […] Hitze entsprechend Klimaanlagen, die stärker in Fahrzeugen beansprucht werden, da dass der Kunde verlangt -. Dass man eher mal einen Ausfall hat, den man dann wieder reparieren muss. […]	33	33	Disruption in air-conditioning for customers which lead to more repairs and therefore to higher cost.
D	U: […] Kältewellen sind es dementsprechend die Startbatterien, die dann eher mal den Geist aufgeben. Im Schnitt hält eine Batterie im Taxigewerbe zwei Jahre. Im Gegensatz dazu hält sie im Privaten sieben Jahre. Also, eine stärkere Beanspruchung. Und dadurch hat man dann -. […]	33	33	Breaking down of starter batteries due to cold waves. Higher stresses for electronic equipment.

Risks – Physical				
D	U: […] Oder eine Umwälzpumpe von dem Kühlwasser nicht funktioniert, weil der Kreislauf inzwischen so groß ist von dem Kühlwasser, dass die Füße im Auto kalt werden. Das ist natürlich nicht gut für die Fahrer, weil sie dann schneller krank werden.	33	33	Breaking down of re-circulation pump which is necessary for car heating. Therefore, drivers become sick faster.
D	U: […]Es ist einmal ein Verkehrsschild umgefallen -. I: Ok, und dann auf das Auto gefallen. U: Auf das Auto drauf gefallen. Baustellenschilder.	128	130	Strong wind leads to damage on the vehicles.
D	U: Da könnte ich etwas anfügen. Sonne bzw. UV-Strahlung auf die Fahrzeuglacke. Dass die dann mit der Zeit stärker beansprucht werden, als in den Jahren zuvor. Wir haben solche Folienautos zum Teil.	138	138	Higher stresses to lack on vehicles.
E	U: […] Winter eher, weil wir müssen dafür sorgen, dass die Startbahn und Flugbetriebsflächen einsatzfähig sind und da ist das größte Hindernis am Ende des Tages ganz klar Schnee. […]	18	18	Higher afford through de-icing of runways and flight lines due to heavy snow.
E	U2: Ich hätte jetzt an die Beschaffung von Enteisungsflüssigkeiten gedacht. U1: Das war das Einzige, was negativ, nicht durch Erwärmung, sondern durch Schneefall, auftrat: Dass die Lastwagen, welche Flugzeugflächenenteisungsmittel an Bord hatten, nicht zum Flughafen durchkamen. Ich würde mal sagen, wir sind mit einem blauen Auge davongekommen. Es hat gerade noch hingehauen, aber es war knapp.	22	23	Disruption of supply in de-icing agent in winter times.
E	U: Und das Zweite ist, dass wir die Flugzeugabfertigung ab Windgeschwindigkeiten von, ich glaube, 60-70 km/h einstellen, weil das dann zu gefährlich ist, mit Klappen, mit wackelnden Fahrgeräten.	31	31	Disruption of aircraft handling at a wind speed of 60-70 km/h therefore cancellation of flights.

(Own illustration.)

Table 44: Interview statements on competitive risks

Risks – Competitive				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	U: Auch mit solchen Kettenwirkungen, die dann also -. Wenn in Dresden zum Beispiel, ist ja kein Hub, sondern Dresden ist Zubringerflughafen und man fliegt nach Frankfurt oder nach München. Und wenn wir diesen Anschlussflug dann nach Südostasien nicht bekommen, den Nachtflug, dann haben wir ein riesiges Problem. Also halten wir auch im Winter logistisch immer Busse in Bereitschaft und beobachten die Wettersituation Tag und Nacht durch ein diensthabendes System. Damit wir also eigentlich auf Sicherheit fünf, sechs Stunden bevor der Flug erst in Dresden gecancelt wird schon ein Bus losschicken können, der die Gäste schon mit Sicherheit in Richtung Frankfurt bringt oder Richtung München.	71	71	Restriction in services due to heavy snow. Loses of flight because of airport closure on this day.
A	U: […] Dann könnten natürlich im Umfeld Umsätze ausfallen oder wenn jemand nur noch Flusskreuzfahren anbietet und die Donau hat in diesem Jahr entweder Hochwasser oder Niedrigwasser, dann bleibt das Schiff liegen. Bei uns mischt sich das alles, durch unser breites Produktangebot. […]	97	97	Lean product portfolio cause to more cancelled services, e.g. high or low water levels lead to cancelled ship operations on rivers. This can lead to customer dissatisfaction.
A	U: […] Das schlimmste Szenario ist, das auch Energieausfälle da sind, es geht nicht nur um Klimaveränderungen, sondern auch um Strahlungsveränderungen und solche Dinge. […]	97	97	Damage of energy supply for computers.
B	U: […] Das haben wir denen schon einmal mit beigebracht. Wir haben uns mit Schneeräumtechnik, die uns die Industrie nicht liefert, beschäftigt. Wir wollten eigentlich für diese Wintersaison zwei Schneepflüge haben. Nur wissen wir jetzt ziemlich genau, dass die Industrie nicht in der Lage ist, die Schneepflüge bis zum Winter herzustellen. […]	128	128	Restriction in operations in the winter time, because of not supplied equipment.
C	U: Na ja klar. Bei uns ist Niederschlag, viel Regen oder so spielt uns immer in die Karten, und Schnee. Voriges Jahr im Dezember war es ganz gravierend, der ganze Dezember war richtig viel Schnee und wir konnten das einfach nicht schaffen, was da angefragt wurde. Wir hatten so viele Aufträge absagen müssen oder Anfragen absagen müssen. Das ging gar nicht.	92	92	Long periods of precipitation lead to higher demand, which cannot be serviced through the transportation provider.
C	I: […] Was denken Sie, welcher Effekt ist stärker, der positive oder der negative? Also, der Umsatzeffekt -. U: Man muss sein Geschäft immer langfristig sehen. Kurzfristig ist das schön, wenn man dann mal ein bisschen mehr hat, aber langfristig fehlt es natürlich, wenn man so viel absagen muss. Der negative Effekt ist -. […]	99	100	Weather impacts especially heavy precipitation are positive in the short run, but negative in the long run.

Risks – Competitive				
D	U: Mit der Luftfeuchte dann haben wir hier schon zu kämpfen. Auch mit der Gesundheit der Fahrer, denke ich. Weil diese müssen sich dann dementsprechend vor UV-Strahlung schützen. Da wird bestimmt wieder ein größerer Teil krank sein […]	40	41	Impacts on the health of transportation drivers through air moisture and radiation.
D	U: […] In der einen Nacht, wo Fluss A über die Ufer trat, war ich selber zum Glück nachts draußen und habe bloß immer über Funk mitbekommen: "Die Straßen sind gesperrt, die Straßen sind gesperrt. Oh, jetzt haben wir hier noch einen Wassereinbruch." […] Da muss man eben einen Umweg fahren und das muss der Kunde dann in Kauf nehmen. […]	88	88	Closed routs through flooding lead to detouring and customer dissatisfaction.
D	I: Haben Wind und Sturm in der Vergangenheit auf Ihre Beschaffung einen Einfluss gehabt? U: Auf die Beschaffung nicht. Aber auf den allgemeinen Fahrbetrieb. Baum umgestürzt. Durch Stürme waren Straßen gesperrt und wir mussten Umwege fahren. Das hat schon einen Einfluss. […]	125	126	Strong winds and storms lead to impacts on operations due to fallen trees and therefore to detouring.
E	U: […] Wind ist in Ausnahmefällen ein Problem. Wir haben selbst bei Kyrill hier Landungen gehabt. Das hat allerdings dafür gesorgt, dass wir ab gewissen Windgeschwindigkeiten die Abfertigung einstellen müssen. Das kann schon einmal passieren. […]	18	18	Above certain wind intensity, the check-in in airports must close.
E	U: […] Wir mussten enteisen auf Teufel komm raus, weil es die ganze Zeit weitergeschneit hat. Wir haben auch rechtzeitig geordert und der LKW ist bei Ort A an Fluss A hängen geblieben und stand da drei Stunden lang im Stau. I: Welche Konsequenzen ergaben sich dann daraus? U: […] Aber wir hätten im Prinzip drei, vier Stunden später den Flughafen dichtmachen müssen.	25	27	Heavy snow lead to disruptions in supply of equipment to maintain the own operations. An airport need de-icing agent for the airplanes.

(Own illustration.)

Table 45: Interview statements on financial risks

Risks – Financial				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	U: […] Da steigen einfach die Kosten. Klimaanlagen sind einfach teuer, also das ist ganz klar. Wenn Sie dann also auch noch Wasser bereitstellen müssen, um einfach auch die Arbeitsbedingungen zu schaffen, damit der Mitarbeiter nicht in der Mittagspause selber Wasser holen geht, oder sich ein Eis holen geht. […]	89	89	Rising cost due to air-conditioning systems. Water supply for employees.
A	U: […] Bilanztechnisch, nimmt natürlich zu, dass sie also mehr Anlagevermögen brauchen. Also wenn sie Klimaanlagen einbauen müssen, müssen die natürlich auch abgeschrieben werden, das ist ganz klar. Wenn sie in den Bussen bessere Technik einbauen müssen, höherwertigere Klimaaggregate mit höheren Verbräuchen, belastet das die Verbrauchskosten und natürlich auch die Abschreibungskosten, das ist ganz klar.	89	89	More capital assets e.g. air-conditioning systems. Optimised technical aspects for busses. Air-conditioning systems lead to higher consumption costs. Higher amortization costs.
A	I: […] im Januar Reisebusse vorhalten, falls der Flug von Dresden nicht nach Frankfurt geht. Und hatten auch, ich sage jetzt mal, von einem erhöhten Risikomanagement gesprochen, was ebenso zusätzliche Kosten einfach nach sich zieht. Sie hatten auch gerade noch mal gesagt, dass Sie mehr investieren zum Beispiel in die Busse, da brauchen Sie ein paar mehr Busse, die Sie bereithalten. […] U: Das stimmt.	92	93	Higher cost through investments in more busses.
A	I: Das wäre so etwas wie Personalkosten als zusätzliche Investitionskosten. U: […] Man kann, wenn man zum Beispiel Busse, die werden sonst im Winter, im Januar und Februar zum Beispiel abgemeldet. Wenn wir die aber zusätzlich für ausfallende Flüge auch in Bereitschaft halten müssen, können wir die nicht abmelden, versicherungstechnisch. Sondern die müssen in Bereitschaft sein. Ich kann nicht alle Busfahrer in den verdienten Urlaub schicken, wo wir gern sehen, dass der einfach nur gemacht wird […] Also man hat schon mehr Aufwand, um das alles bereitzuhalten. […]	94	95	In case of flight cancellation lead to higher standby costs for busses (e.g. incurrence) and driver (personnel costs)
B	U: Ja, das hatte ich schon gesagt, das sind in aller erster Linie jetzt die Belüftung in den Fahrzeugen, die sich geändert hat. Wir werden sicherlich auch morgen über Klimatisierungen sprechen. Wir werden uns aber genauso gut darüber unterhalten müssen, wie wir Energieverbräuche senken. Nun sehe ich das nicht nur klimatisch. Ich sehe das so aus Kostengründen.	19	19	Cost due to air-conditioned vehicles.

Risks – Financial				
B	I: Gab es denn schon in der Vergangenheit schon mal, sage ich jetzt mal so, in Bezug auf den Klimawandel bezogene Beschwerden? Also, dass es Beschwerden von Ihren Kunden gab, dass es zu heiß in den Bussen ist oder so was? U: Ja na freilich. Das wäre ja unnatürlich.	51	52	Customer complaints through climate change.
B	U: […] Das sind schon Klimaerscheinungen. Das ist überhaupt gar keine Frage und dort müssen die sich unmittelbar damit auseinandersetzen. Das kostet Geld. […]	118	118	Climate change lead to higher costs in general.
C	U: Naja, sagen wir mal so, sehr hohe Temperaturen in der Woche führen schon hin und wieder mal dazu, dass man das Gefühl hat, dass es eine allgemeine Trägheit in der Bestellung oder so gibt, dass eben nicht so viel davon Gebrauch gemacht wird, von unserer Dienstleistung. […] I: Was denken Sie, woran liegt das? U: Keine Ahnung. Die Leute bleiben dann vielleicht in ihren Wohnungen und gehen nicht weg. Bleiben zu Hause oder in ihrem Garten und rühren sich da nicht weg, […].	36	38	Fewer trips on hot days, potentially customers stay at home on these days.
C	U: Weil wir, so wie die Kunden weggehen möchten, so werden wir gefordert. […] Was das normale Tagesgeschäft betrifft, also in der Woche ist es alles nicht so dramatisch. Aber das meiste machen wir fast am Wochenende oder auch abends. Sodass man sagen kann, wenn es lange kalt ist, dann wollen die Leute einfach nicht mehr wirklich gern weggehen. Ich weiß ja nicht, wie es Ihnen da geht, aber mir geht es auch so, ich habe dann auch keine Lust mehr.	42	42	Extreme cold evenings lead to fewer trips, because customers stay at home.
C	U: Ja, oder wenn es stürmt. Da irgendwo zu einer Party gehen. So spontane Sachen gleich gar nicht […] und das wechselt bei uns eben auch.	44	44	Strong wind storm lead to fewer trips, because customers stay at home.
C	I: […] die Personalkosten, die steigen […], aufgrund der Klimaanlage, wenn die da stärker zum Einsatz kommt. […] U: Ok, Personalkosten. Ja, das ist ein Argument, wenn die krank werden, das ist schon klar. Ja. Guter Hinweis.	147	148	Rising in personnel costs due to diseases.
D	U: Einmal durch die Stadt, über die Autobahn und wieder auf der anderen Seite zurück. Das hat sich wirtschaftlich gut ausgewirkt, aber danach blieben die Touristen aus, was dann wieder einen Einbruch des Umsatzes für das darauf folgende Jahr zur Folge hatte.	90	90	Current weather impacts have long run impacts for tourism therefore profits of the next year will decrease. (due to flooding)
D	I: Können Sie das prozentual beziffern, wie bei Ihnen der Umsatz eingebrochen ist? U: Wir hatten bestimmt 10% bis 20% weniger Umsatz in dem Jahr danach und in den entsprechenden Monaten.	91	92	Due to flooding 10-20 % profit decrease.

Risks – Financial				
D	U: Betroffen sind die Kraftstoffkosten, die durch den Klimawandel steigen, da es ja weniger Öl gibt und dadurch die Ölpreise und damit die Dieselpreise steigen. Die Kraftstoffpreise sind durch den Klimawandel extrem gestiegen. Dort haben wir extreme Kostenerhöhungen in den letzten Jahren erfahren.	154	154	Extreme rising fuel cost due to climate change.
D	U: Aufgrund der letzten Jahre, wo wir immer stärkere Winter hatten, musste man eben immer mehr Winterreifen kaufen oder Reifen mit mehr Profil haben. Das erhöht die Kosten der Reifen. Also, Betriebsmittel steigen meistens.	154	154	Rising cost in operational material e.g. more tires or tires with higher treads.
D	U: Höhere Reparaturkosten. I: Reparatur- und Wartungskosten. U: Wartungskosten steigen damit auch. Werkstattkosten.	158	160	Higher maintenance costs.
E	I: Gut. Zum Thema Entsorgung. […] U1: Nur in der Facette, in der es auch bei der Beschaffung eine Thematik hat, nämlich die Ableitung von diesen Enteisungsmitteln. Das heißt also, weil wir dort mehr sprühen müssen. Das müssen wir natürlich bei uns im Entwässerungssystem stauen. Das können wir auch, dazu sind wir technisch in der Lage und das wird dann in das Netz der Stadtentwässerung abgegeben. Für uns entstehen dann Entwässerungskosten, weil das ist zwar biologisch abbaubar, […] aber es darf nicht in die Vorflut abgeleitet werden, aufgrund von CSB-Werten und von daher wird es zwischengestaut.	60	61	Rising dewatering costs due to higher amount of de-icing agents in winter times.
E	U1: Es ist nicht so richtig billig. Also, wenn es um das Thema Flächenenteisung geht, kann es sein, dass wir an einem Tag 20.000 € auf die Piste schmeißen. Das ist also schon ein Faktor, wenn sie da mal zehn Tage davon haben, dann haben sie einen sechsstelligen Betrag nur für das Enteisungsmittel.	114	114	More use of de-icing agents lead to higher operation costs per day.

(Own illustration.)

Table 46: Interview statements on regulatory risks

Risks – Regulatory				
Comp.	*Statement*	*Begin*	*End*	*Comment*
No regulatory risks due to weather extremes were mentioned.				

(Own illustration.)

Table 47: Interview statements on physical opportunities

Opportunities – Physical				
Comp.	*Statement*	*Begin*	*End*	*Comment*
No physical opportunities due to weather extremes were mentioned.				

(Own illustration.)

Table 48: Interview statements on competitive opportunities

Opportunities – Competitive				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	I: […] Sie meinten, aufgrund der Klimaveränderungen verschiebt sich jetzt der Reisezeitraum. Also wir haben jetzt nicht mehr den engen Reisezeitraum Juli August, sondern das verschiebt sich so auf die Ränder. Da hatten Sie halt auch auf diese Verlagerung angesprochen. Ist das ein Umsatzplus für Sie? U: Für uns speziell kann es ein Plus sein. Weil wir ganz einfach aus der Hochsaison, aus der preisintensiven Hochsaison immer mehr in die Nebensaison gehen können. Also man hat längere Zeiträume, um die Hotels auszulasten, die Kapazitäten, sogar die Flüge, die Fluggestaltung.	90	91	Shifting in travel time form high season to low season therefore rising in demand of flights.
C	U: Wir fahren Menschen von A nach B und fahren einfach. Und ob es kalt ist, ob es warm ist, wir fahren immer, ob es regnet oder schneit […] Starkregen oder überhaupt ein plötzlich eintretender Regen ist immer gut für das Geschäft, oder wenn viel Schnee liegt, ist auch gut für das Geschäft. Also, von daher, positiv.	24	24	Suddenly appearance of high precipitation leads to higher demand of driving service.
C	U: Schnee oder Regen ist egal. Wenn es schneit, haben wir viel zu tun.	110	110	Heavy snow or rain leads to higher demand of driving services.
D	I: Darf ich daraus schlussfolgern, das eigentlich solche Extreme für Sie von Vorteil sind? U: Das könnte man daraus schlussfolgern, dass das von Vorteil ist. Zumindest die ersten Tage. Wenn das dann länger andauert, dann gewöhnt sich der Bürger wieder normal daran und kommt damit klar. […]	45	46	Extreme temperature leads to higher demand in driving services as well as heavy snow in the first days of occurrence.
E	U: Also, ich sehe es, wie gesagt, wo man es greifen kann, letztendlich nur in dem Bereich des Outbound-Tourismus, des klassischen Charter-Tourismus, Urlaubstourismus, wo wir von schlechtem Wetter profitieren. […]	55	55	Bad local weather conditions lead to more tourism and therefore higher demand of flights.

(Own illustration.)

Table 49: Interview statements on financial opportunities

Opportunities – Financial				
Comp.	*Statement*	*Begin*	*End*	*Comment*
D	I: Ja, genau. Und solche Extreme haben im Allgemeinen, hatten Sie vorhin gesagt, einen positiven Einfluss auf den Umsatz. U: Haben einen positiven Einfluss.	165	166	Extreme weather conditions have a positive impact on profit.
E	U: […] Wenn der Klimawandel käme und es würde hier im Schnitt wärmer werden, hätten wir davon sogar einen positiven Aspekt, wir bräuchten wahrscheinlich weniger Enteisungsmittel einsetzen, was uns Geld sparen würde.	33	33	Decreasing cost in deicing agents.
E	U: […] Schlechtes Wetter im Herbst und im Winter ist gut, oder auch noch im Mai oder Juni ist hervorragend für unsere Buchungslage, weil die Leute dann in die Reisebüros rennen und Urlaubsreisen in den Süden buchen. […]	43	43	Due to bad weather conditions, rising in flight demand, this lead to higher profit.

(Own illustration.)

Table 50: Interview statements on regulatory opportunities

Opportunities – Regulatory				
Comp.	*Statement*	*Begin*	*End*	*Comment*
No regulatory opportunities due to weather extremes were mentioned.				

(Own illustration.)

Table 51: Interview statements on technological adaptation measures

Adaptation measures – Technological				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	U: Ja. Ganz wichtige Frage, denn die Klimaanlagen, […] und die Deutschen sind ja in der Busherstellung immer Spitzenreiter gewesen, die taugen für die heutigen klimatischen Verhältnisse in Europa überhaupt nichts mehr. Deswegen gab es da schon Anpassungen in der -. Trotzdem gibt es noch Busse, zum Beispiel, deren Klimaanlagen unter Extremverhältnissen im Sommer ausfallen. Und diese Ausfallwahrscheinlichkeit müssen wir natürlich senken, indem wir tatsächlich darauf achten, welche Klimaanlagen werden eingebaut. […]	41	41	Installation of optimised air-conditioning systems for busses.
A	U: Inzwischen haben wir zwei unabhängig voneinander agierende Kühlsysteme für die EDV. Wenn eines ausfällt, gibt es sogar ein Notstromaggregat, was anspringen kann, wenn die Stromversorgung ausfällt. Für uns wäre das eine Katastrophe, wenn die EDV ausfällt. […]	51	51	Protection of energy failure due to extreme heat. Installation of independent cooling systems and an emergency generator for EDV.

Adaptation measures – Technological				
A	I: So am Gebäude selbst, ich sehe jetzt gerade bei Ihnen die Jalousien. Was haben Sie da vielleicht verändert im Zuge der Klimawandelanpassung? U: Also, das war schon ein großer Teil der Anpassung. Dass wir das verändert haben und es muss ausreichen. Man kann es nicht besser machen, wie wir es jetzt gemacht haben. Man müsste jeden Raum also klimatisieren, was wir hoffen, dass wir an dieser Ausgabe vorbeigehen können.	52	53	Air-conditioning of working areas through installation of window shades.
A	U: Ja. Also wir haben in den letzten zehn Jahren alle unsere Räume, in denen produziert wird, nicht in den Verwaltungsräumen, aber in den Räumen, wo also wirklich auch an heißen Tagen ununterbrochen gearbeitet werden muss, haben wir Klimaanlagen eingebaut.	43	43	Installation of air-conditioning system in working areas.
B	U: […] Richtig ist natürlich, dass die Qualität eine andere wird und das möchte ich mal im Hinblick gerade auf unsere Fahrgäste mit sehen, die natürlich jetzt andere Anforderungen stellen. Das könnte z. B. sein: klimatisierte Räume. Wir haben also teilweise Unterrichtsräume hier schon entsprechend nachgerüstet. Wir beschäftigen uns auch mit Klimatisierung oder, ich sage mal, mit dem Raumklima in den Fahrzeugen. […]	7	7	Air-conditioning of working areas and vehicles.
B	I: Sie sagten, die Belüftung muss sich ändern. Können Sie uns das noch einmal näher erläutern? U: Ah, da gibt es viele Möglichkeiten. Das geht damit los, was wir früher gemacht haben. Wir haben ein Fenster aufgemacht. Das wir uns da besinnen, dass es auch heute noch so etwas gibt. Wir haben also Klappfenster in Fahrzeugen eingebracht, die wir im Sommer aufmachen können. […]	20	21	Installation of top hung windows in trams for air-conditioning, therefore saving cost in electricity.
B	U: […] Wir haben uns auf bewährte Holzfußböden wieder besonnen. Früher haben wir die Fahrzeuge nur aus Holz gebaut und haben dadurch Isolationseigenschaften bekommen, die also ganz anders fungieren als das jetzt, meinetwegen, mit Metall ist. Wenn sie heute in der Straßenbahn stehen und kalte Füße bekommen, ist es unangenehm. Wenn sie auf einem Holzfußboden stehen, werden sie feststellen, dass es viel angenehmer ist. Und da haben wir noch nicht ein Kilowatt verbrannt. […]	23	23	Installation of wooden floors in trams therefore good isolation of vehicles and cost savings in electricity.
B	U: […] angenehmere Räume schaffen. Und das ist an und für sich jetzt in dem ganzen Zusammenhang wieder mit zu sehen. Wir werden uns Isolationen hernehmen müssen -. Schon eine getönte Scheibe bringt schon einmal ein ganz anderes, sagen wir mal, Empfinden hinter der Scheibe. Wenn sie heute hinter ganz normalem Fensterglas sitzen, dann brennt ihnen das auf der Haut und wenn sie jetzt hinter einer getönten Scheibe sitzen, dann ist gerade die ultraviolette Strahlung, gerade durch das, wird sie zurückgehalten. Es ist also auch schon ein anderes Aufheizen im Fahrzeug mit drin. […]	37	37	Tinted windows protect customers against heat and radiation.
B	U: […] Dass wir die Arbeitsplatzklimatisierung haben, […] In der Form, dass wir auch einen Arbeitsplatz bieten, wo man also auch acht Stunden konzentriert arbeiten kann. Dass man also auch aufpasst, dass man nicht von Erscheinungen, die also hohe Temperaturen z. B. mit sich bringen, wo man schwitzt, sich unwohl fühlt, dass die auch dann letztendlich negativ auf den Fahrer mit einwirken. […]	42	42	Air-conditioning of working area of the driver due to extreme heat, which lead to decreasing in concentration and indisposition.

Adaptation measures – Technological				
B	U: […] Wir haben zwar einiges gemacht, zu mindestens, was die Oberleitung betrifft. Gerade bei Wettererscheinungen, Eisregen, Niederschläge. An und für sich immer nutzbar, ist es aber immer die Frage, wie das wirklich auftritt. […]	54	54	Optimization of overhead cables.
B	U: […] Sicherlich muss man jetzt die ganze Fracht der Elektronik, die Antriebstechnik -. Die muss man natürlich jetzt so konzipieren, dass wir natürlich auch bei feuchten, ich sage mal, Wettererscheinungen, ob das jetzt Nebel ist, ob das Niederschläge sind -. Ja, da muss man so ausrüsten, dass gerade heute die Luft gekühlten Maschinen oder Motoren, ich sage mal, bei dem feuchten Wetter mit arbeiten.	60	60	Optimization of electronic components which are resistant against moisture.
B	U: Nein. Wir müssen schon im Verkehr darauf achten, dass wir Niederschlag abführen, so wie wir das früher auch gemacht haben. Wir brauchen Schnittgerinnung, wir müssen darauf einstellen, dass wir nicht Sachen bauen, wo wir mit dem Fahrzeug lang fahren und der Fahrgast will einsteigen und wird vollgespritzt. […]	65	65	Installation of drainage systems along the routes.
B	U: […]Hoffentlich blicken wir das auch im nächsten Winter. Ich denke wir haben uns entsprechend darauf vorbereitet. Wir bevorraten uns mit Salz, wir bevorraten uns mit Räumtechnik, mit Schneeschiebern, die altherkömmliche Technik, die haben wir auch mit da. […]	132	132	Storage of road salt and snow slides for winter time.
C	I: […]oder haben Sie da Autos anders geordert, also anders im Sinne von, dass Sie die halt temperaturtauglich im positiven, negativen Bereich gemacht haben? U: Unsere Fahrzeuge haben eine Klimaanlage.	49	50	Air-conditioning of vehicles.
D	U: Sowohl als auch. Hitze entsprechend Klimaanlagen, die stärker in Fahrzeugen beansprucht werden, da dass der Kunde verlangt -.	33	33	Air-conditioning of vehicles.
D	U: […] dann sind es meistens die Taxen, die sich auf den Hauptstraßen noch durchwühlen können. Wenn es so wird jeden Winter, dann werden wir wahrscheinlich die Autos umbestellen müssen, also mit Allrad. Damit wir dann die Hänge hochkommen an der Seite.	78	78	Optimization of cars with all-wheel-function for time with heavy snow.
D	U: Die Großraumtaxen bei mir sind alle mit schwarzen Scheiben hinten. Dass es im Innenraum kühler ist und weniger UV-Strahlung durchlässt, weil die ziemlich große Scheibenflächen haben. Sieht nicht bloß schick aus, sondern es ist im Sommer für die Fahrgäste auch angenehmer. Von der Sonne her, wenn man hinter einer solchen Scheibe sitzt und die Klimaanlage an ist -.	148	148	Installation of tinted windows in taxis against radiation and air-conditioning.
D	U: […] Aber, dass ich das jetzt bei den PKWs permanent machen würde, würde ich nicht sagen, weil die schon von Haus aus mit UV-Schutz-Glas, mit grünlichen oder bläulichen Scheiben -. I: Ausgestattet sind.	150	151	Cars have window glass against radiation innately.
E	U: […] Also, auch Wasser ist nicht problematisch, oder nur geringfügig problematisch. Da sind bei uns die Sicherheitspuffer, würde ich einfach mal sagen, so groß, dass das kein Problem ist. […]	18	18	Safety buffer in drainage system against intensive rain or snow fall.

Adaptation measures – Technological				
E	U: […] Weil bei größerer Hitze können die Flugzeuge weniger Zuladung mitnehmen. Das hat für uns keine Bedeutung mehr. Wir haben das, als wir unsere Start-/ Landebahn saniert haben, berücksichtigt und noch ein paar Meter dran gehängt. Insofern haben die Flugzeuge, die von uns regelmäßig aus operieren, inzwischen da auch keinerlei Restriktionen mehr. […]	31	31	Extension of runway.
E	I: Wenn jetzt ein Starkniederschlag ist, fließt das auf den Start-/ Landebahnen ab? U1: Wir haben unter dem kompletten Parallelrollweg eine Entwässerungsleitung, die bis zu 3 m Durchmesser hat, […] Hier hinten haben wir ein Regenrückhaltebecken, was ziemlich groß ist. Das ist uns übrigens 2002 bei dem Niederschlag sogar unterspült worden. Das heißt, wir haben dann noch einmal kräftig nachgebessert, haben es noch einmal etwas größer gemacht.	72	73	Drainage system along the parallel runway as well as rain detention reservoir.

(Own illustration.)

Table 52: Interview statements on economic adaptation measures

Adaptation measures – Economic				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	U: […] Wichtig ist, dass wir unseren Kunden immer wieder die Möglichkeit geben, dass er also wettergeschützt, sozusagen, reisen kann. Wir kommen dem Kunden entgegen, indem wir ihn an der Haustür abholen. Und inzwischen steigen wir dann in die Busse bzw. in die Flugzeuge nur an den Stellen, wo die also überdacht sind, an diese Schnittstellen. […]	39	39	Transportation of customers without contact of weather impacts therefore rising customer satisfaction.
A	U: […]Wenn in Dresden zum Beispiel, ist ja kein Hub, sondern Dresden ist Zubringerflughafen und man fliegt nach Frankfurt oder nach München. Und wenn wir diesen Anschlussflug dann nach Südostasien nicht bekommen, den Nachtflug, dann haben wir ein riesiges Problem. Also halten wir auch im Winter logistisch immer Busse in Bereitschaft und beobachten die Wettersituation Tag und Nacht durch ein diensthabendes System. Damit wir also eigentlich auf Sicherheit fünf, sechs Stunden bevor der Flug erst in Dresden gecancelt wird schon ein Bus losschicken können, der die Gäste schon mit Sicherheit in Richtung Frankfurt bringt oder Richtung München. […]	71	71	Fast reaction through tracking a weather situation system to local weather conditions and their potential impacts to services. Therefore shift of transportation mode.
A	U: […] Und wichtig, Verhandlungsmacht der Arbeitnehmer. Also, dieses Empowerment, damit die entscheiden können, handlungsfähig sind. Das sind Dinge, die bei uns geregelt sind. Notfallszenarien existieren bei uns, die bestimmt nicht jeder hat.	97	97	Development of emergency scenarios to maintain the operations of employees.
A	U: Also, die, die ihren Arbeitnehmern keine Verhandlungsvollmacht geben oder eben Entscheidungsvollmacht geben, die werden diese Situation, werden, wenn die Entscheidungswege zu lang sind, wenn da Kommunikationswege noch gestört sind, wenn man telefonisch nicht erreichbar ist, der entscheiden muss. Also, dann ist der Flieger weg oder ist schon abgestürzt oder das Schiff schon untergegangen oder -. Also, ja, es ist auch das an den ganzen Schnittstellen wichtig. […]	111	111	More authority to decide for employees in extreme situation especially weather extremes.

Adaptation measures – Economic				
B	U: […] alle Flutgelder, die geflossen sind, eigentlich so angepackt, dass wir gesagt haben: "Lasst uns die Anlagen so bauen, nicht reparieren, so bauen, dass wir in den nächsten 20 Jahren nicht mehr ran müssen.“ […]	116	116	Investments in sustainable constructions to protect transportation infrastructure in the next years.
D	U: Wir statten vorm Winter immer alle Autos mit neuen Winterreifen aus und lassen die Reifen bis zum Sommer alle runterfahren. Bis sie ganz runter sind und dann bloß für eine kurze Zeit Sommerreifen und dann wieder für den Winter neue Winterreifen. Um den extremen Witterungsbedingungen im Winter, Schneefall, mit neuen Winterreifen entgegenzuwirken. Sicherheit und diese Geschichten. Und im Sommer kann ich auch Winterreifen -. Und damit verbrauche ich im Endeffekt weniger Reifen, die ich kaufen muss. Damit habe ich auch weniger Kosten und schone die Umwelt, weil ich ja weniger Reifen entsorge.	76	76	New winter appropriable tiers every year to have safety standards. Change to summer tiers in late summer. Therefore lower cost for tiers, because of a lower necessary amount of tires in general.
E	I: Sonstiges zur Beschaffung? Vielleicht auch perspektivisch? U1: Wir haben diesbezüglich auch unsere Lagerkapazitäten erhöht. Das war definitiv eine Folge aus den Erkenntnissen des letzten Winters.	28	29	Increasing of storage in de-icing agent.

(Own illustration.)

Table 53: Interview statements on ecological adaptation measures

Adaptation measures – Ecological				
Comp.	*Statement*	*Begin*	*End*	*Comment*
D	U: […] Wir haben es mit Flüssiggas probiert. Das hat aber nicht so richtig funktionieren wollen, weil -. Hat sich mit der erhofften Ersparnis, von den Kosten her, nicht eingestellt. Die sind zwar umweltfreundlicher und man trägt was dazu bei, aber durch das viele Starten und Anfahren am Halteplatz verbraucht man doch mehr Benzin als Gas und damit hat sich das wieder ausgeglichen.	31	31	Shift from gasoline to liquid gas. Liquid gas is more ecological friendly. Cost compensation due to savings in fuel amount.
D	U: Also, um die Temperatur -. Das sind ja diese Rußpartikelfilter und dort haben wir jetzt Fahrzeuge, die alle zum Schluss kamen, mit einem Rußpartikelfilter ausgestattet, um das dort zu verbessern. Man tut schon das, was der Markt anbietet, oder der -.	60	60	Installation of soot particle filters in cars to adapt to high temperature.
D	U: Dass die Leute so wirtschaftlich wie möglich fahren. Kunden ausladen und am besten am nächsten Halteplatz stehen bleiben und keine leeren Kilometer fahren. Damit sie nicht noch zusätzlich Abgase und Wärme produzieren. Im Sinn der Umwelt.	62	62	Reduction of blank kilometer due to the stop at the place after a service ride.

Adaptation measures – Ecological				
D	U: Wir statten vorm Winter immer alle Autos mit neuen Winterreifen aus und lassen die Reifen bis zum Sommer alle runterfahren. Bis sie ganz runter sind und dann bloß für eine kurze Zeit Sommerreifen und dann wieder für den Winter neue Winterreifen. Um den extremen Witterungsbedingungen im Winter, Schneefall, mit neuen Winterreifen entgegenzuwirken. Sicherheit und diese Geschichten. Und im Sommer kann ich auch Winterreifen -. Und damit verbrauche ich im Endeffekt weniger Reifen, die ich kaufen muss. Damit habe ich auch weniger Kosten und schone die Umwelt, weil ich ja weniger Reifen entsorge.	76	76	Due to fewer disposals of old tiers, because of less use of tiers and therefore cost savings.
D	U: In Form von ALITA-Taxi. Ist auch eine gute Sache. Damit entlasten wir auch die Umwelt, weil dadurch kein Bus mit drei Personen durch die Stadt geschickt. Da wird ein Taxi gerufen und der fährt die Kleinlinien, wo es sich nachts nicht lohnt und wo die einen großen Bus schicken. […]	187	187	Cooperation with taxi company at night, to serve small routs where a big bus is not necessary.
E	U1: Nicht unbedingt, weil dort sind wir in der Steuerung unseres Entwässerungssystems immer besser. Wir versuchen das Abwasser zu konzentrieren, was belastetes Abwasser betrifft. Wir generieren dadurch aber auch zunehmend unbelastetes Abwasser. Und das hochbelastete Abwasser kostet uns genauso viel wie wenig belastetes Wasser. Liter gleich Liter für die Stadtentwässerung. Das heißt also, wenn wir das schaffen, höher konzentriert in das System der Stadtentwässerung reinzubringen, haben wir da sogar einen Entlastungseffekt. Verbesserte Steuerung bei uns ist Kostenentlastung.	116	116	Optimization of drainage system to concenter waste water and therefore generation of fewer unpolluted waste water.

(Own illustration.)

Table 54: Interview statements on social adaptation measures

Adaptation measures – Social				
Comp.	*Statement*	*Begin*	*End*	*Comment*
A	U: Wasserbereitstellung und solche Dinge sind heute üblich oder eben Ventilatorenbereitstellung. Dann Kühlung der EDV.	49	49	Water and ventilators for employees.
A	U: Gut. Nur wenn es unsere Kreuzfahrten betrifft und das sind natürlich Ereignisse, die also Schiffe in Gefahr bringen usw. Genauso katastrophal für das Kundendenken in der Vorbereitung auf die Reisen wie andere Klimaextrema. Da haben wir natürlich zu tun, um den Leuten zu erklären, dass das nur äußerst selten ist. Und auch da sind wir gezwungen immer positiv -. Oder auf sichere Reisezeiten zu verweisen. Wo man da auch sicher sein kann. Wir müssen diesen Vorbehalt, dass solche Dinge passieren können, muss man immer hinweisen. […]	83	83	Development of information sheet about climate extremes which can affect transportation mode, especially cruise ships for customers.

Adaptation measures – Social				
B	U: […] ich sage mal auch eine Teilklimatisierung möglich für unsere Arbeitsplätze. Für den Fahrer haben wir schon eine Arbeitsplatzklimatisierung. Und wir beschäftigen uns mit dem Fahrgastraum, damit, dass wir also Belüftungsanlagen installieren, die dann den Aufenthalt im Fahrzeug erträglich machen. […]	7	7	Air-conditioning for the driver's working area.
B	U: […] Wir haben sehr viele neue Kollegen bekommen. Da haben wir gesagt: "Kommt, wir zeigen euch einmal, wie man eine Weiche freischiebt oder an welchen Stellen einer Weiche ich natürlich zuerst schauen muss." Unsere alten Hasen wissen das, vielleicht haben sie es auch wieder verlernt, den haben wir es auch mitgesagt. Aber wie verhalte ich mich denn bei solchen Sachen. […]	128	128	Employee trainings for new and old employees in extreme situations, e.g. maintenance in winter times.

(Own illustration.)

Table 55: Interview statements on political adaptation measures

Adaptation measures – Political				
Comp.	*Statement*	*Begin*	*End*	*Comment*
No political adaptation measures due to weather extremes were mentioned.				

(Own illustration.)

Table 56: Interview statements on barriers of implementation

Barriers of implementation				
Comp.	*Statement*	*Begin*	*End*	*Comment*
No barriers of implementation due to weather extremes were mentioned.				

(Own illustration.)

Table 57: Interview statements on open issues related to stakeholders

Open issues – Stakeholder				
Comp.	*Statement*	*Begin*	*End*	*Comment*
D	U: Von einem Reisebüro aus Ort B. Für die machen wir Ort B/ Region A. Die haben schon gefragt: "Haben Sie Autos mit Klimaanlagen?" Am besten mit schwarzen Scheiben hinten, da der Rentner nicht gerne hinter der warmen Scheibe sitzt, wenn er am Tag fährt.	168	168	Customer request of air-conditioned and tinted-windows cars.
D	I: […] Sagen Ihre Mitarbeiter manchmal etwas zu Ihnen bezüglich der Fahrzeuge? U: Das einzige was sie vorneweg -. Eine Klimaanlage, elektrische Fenster, am liebsten noch mit Automatik. Ein Radio. I: Die wollen definitiv mittlerweile eine Klimaanlage im Auto haben. […] U: Der Kunde fordert das eigentlich. Man kann das nicht mehr ohne anbieten.	180	183	Employees ask employer for air-conditioned cars.

(Own illustration.)

Table 58: Interview statements on open issues related to research

Open issues – Research				
Comp.	*Statement*	*Begin*	*End*	*Comment*
B	U: […] Wir werden sicherlich auch morgen über Klimatisierungen sprechen. Wir werden uns aber genauso gut darüber unterhalten müssen, wie wir Energieverbräuche senken. Nun sehe ich das nicht nur klimatisch. Ich sehe das so aus Kostengründen.	19	19	Further research in low energy air-conditioning.
B	U: […] Jetzt haben wir sie oben auf dem Dach, wo es am heißesten ist. Und jetzt war dieser Hinweis, den ich schon vorhin einmal gegeben habe, die Elektronik muss natürlich jetzt diese Temperaturen aushalten. […]	23	23	Electronic vehicle components should be resistant to extreme heat.
B	U: […] Auf der Straße hat es schon vor 20 Jahren Temperaturen gehabt. Die waren 80, 90 °C. Der Asphalt ist schon immer im Sommer heiß geworden. Wir werden neue Baustoffe suchen müssen. […]	23	23	New heat resistant asphalt materials.
B	U: […] ob das im Fahrzeugbau ist. Wir werden uns mit Isolationen beschäftigen, also, ich sage mal, die nicht aktiv, sondern an und für sich passiv, die auf die Temperaturveränderungen entgegen wirken. Wer hat früher schon groß Fahrzeuge isoliert? Wir müssen uns also auch darüber mal Gedanken machen, wie wir die Fahrzeuge isolieren und da meine ich jetzt nicht den Sommer, sondern auch den Winter. […]	23	23	Need of optimised vehicle isolation for summer and winter time respectively.
B	U: […] Vielleicht müssen wir auch einmal erkennen, dass eine weiße Farbe entsprechend günstiger wirkt als eine Schwarze. Solche einfachen Sachen sollten auch wieder mehr -. […]	27	27	Change of car paint from black to white therefore no heating of vehicle.
B	U: Na, zur Beschaffung. Die Industrie muss sich natürlich auf die veränderten Bedingungen einstellen. Wir werden nicht hinbekommen, dass wir jetzt unsere Fahrzeuge selber konstruieren oder verändern. Wir wollen schon von einer Industrie entsprechend ein Produkt haben, was man natürlich auch einsetzen kann und wir sind gern bereit, dort mitzuwirken und denen auch zu sagen, was wir gebrauchen können. Da haben wir überhaupt gar keine Scheu. Aber die Regeln muss schon die Industrie machen.	32	33	Need for cooperation between vehicle users and production industry in vehicle construction and necessary components.
B	U: […] In den Bussen haben wir schon Klimatisierung, […] Eine stehende Luft wirkt auf den Fahrgast ganz anders als eine sich verändernde Luft und oftmals ist es auch ausreichend, wenn sie zwei, drei, vier °C die Temperatur absenken, d. h. also, wenn ich draußen Temperaturen von 36 °C habe und habe eine niedrige Luftfeuchtigkeit, dann empfinde ich das ganz anders. […] Das sind also auf der einen Seite, kann man sich durchaus damit beschäftigen Trocknungsanlagen. […]	35	35	Research in drying plant against high air moisture in busses.

Open issues – Research				
B	U: […] Vielleicht auch noch durch die Wissenschaft entsprechende Gläser entwickeln, die also eine ganz andere Filterwirkung haben. Nicht bloß die Thermoscheiben. Sie sind ja sehr schwer. Die sind im Fahrzeugbau auch nicht gewünscht. Das man also mit großen Lasten. Das hat wieder was mit Energieverbrauch zu tun. […]	37	37	Optimization in light window glasses with a special filtering of radiation and heat.
B	U: […] Wir werden sicherlich vielleicht in den Reifen andere Erkenntnisse bekommen. Wir werden uns im Winter damit auseinandersetzen, dass wir einen griffigeren Gummi bekommen, dass wir also dort nicht so viel Salz streuen müssen. Aber wir werden uns mit dem Winter, den werden wir nicht abschaffen und bei den Niederschlägen ist dass das selbe. […]	73	73	Optimization in tire treads for better grip on roads in winter times.
C	I: Ok, gut. Denken Sie auch für die Zukunft, dass es da noch irgendwelche Bereiche gibt, die man im Automobilbereich hinzubuchen, hinzukaufen könnte, was es den Gast noch angenehmer machen könnte? Gibt es so was? U: […] Ich weiß nicht, ob es Sitzheizungen für hinten gibt. Keine Ahnung, nicht? I: Wäre das eine Option? U: Das wäre dann eine Option, wo der Fahrgast sich das selber regulieren kann. Wie gerne er es denn warm hat.	57	60	Seat heating for customer with self-regulation.
C	I: Künftig, noch einmal der Blick in die Zukunft. Können Sie sich da irgendetwas vorstellen?[Beschaffung] U: Wüsste ich nicht. Müssen wir halt immer gucken, dass wir gute Reifen haben.	87	88	Equipping with appropriable tiers.
D	U: Positiver Art, wenn unsere -. Da kommen wir zwar in den Bereich Umweltschutz -. Ich bin ja von diesen Hybridautos, wenn es die mit Diesel geben würde im PKW Bereich, begeistert. Wo ich mir vorstellen könnte, was zu tun. Oder was mich sehr reizt, sind diese Wasserstoff-Autos von Daimler, wo ich das meiste Augenmerk drauf lege, das das irgendwann zur Marktreife kommt. Weil die die entsprechende Reichweite haben, dass die sich für unser Business hier lohnen. […]	31	31	Hybrid cars or hydrogen cars which are profitable for business.

(Own illustrations.)

Table 59: Interview statements on open issues related to policy

Open issues - Policy				
Comp.	*Statement*	*Begin*	*End*	*Comment*
D	U: […] Ich würde mir vom Staat wünschen, dass er auch mehr die kleineren Unternehmen unterstützt. Das wäre mein Traum, weil wir ja nicht gerade wenig sind. Wir sind 500 Fahrzeuge in der Stadt. Wenn man das jetzt bloß auf Ort B beziehen würde, weil man die dann unterstützen könnte, weil die tragen ja einen Teil dazu bei. […]	185	185	Support of small companies through government.
D	U: […] Das würde ich mir von Straßenbahnen manchmal wünschen, wenn ich diese nachts durch die Stadt fahren sehe. Riesenlange Schläuche. Schicke, moderne Straßenbahnen, aber es sitzen kaum Leute drin. Das wünsche ich mir, dass die in der Stadt vielleicht nachts eine Pause machen. In Zeiten wo es sich gar nicht lohnt, vielleicht zwischen zwei und vier und man sagt: "Man lässt die Straßenbahn im Depot und spart Personal ein und Energie".	187	187	More cooperation between public transportation and taxi companies by night to save costs.

(Own illustration.)

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Abstract

The thesis aims at corporate adaptation to climate change impacts in the logistics and transportation industry, especially for the model region Dresden. The paper employs two analyses. The first part deals with a review of the current literature within the topic. 20 references are identified and analysed with a data extraction form. More general adaptation measures are identified in the current literature which can be implemented in the corporate strategy. Crucial effects on company's operation and its profit have flooding and sea level rise. In comparison adaptation measures, which are identified within five interviews of transportation providers in the model region Dresden, are of technological nature. The interviewed companies adapted significantly to weather extremes in the past. It is identified that heavy precipitation like rain and snow lead to crucial negative impacts to their operations which cause lost profit and customer dissatisfaction in long periods of time. On the other hand these weather conditions may have positive effects in short periods of time. Region-specific analyses in climate change impacts and the implementation of potential adaptation measures for logistics and transportation companies is still in a stage of infancy. Further research is needed on more region-specific analyses and on logistics companies in the model region Dresden as only five of them analysed in this thesis.

Keywords: Logistics and transportation industry; Climate change impacts; Climate change adaptation; Extreme weather events

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